

Exhibit A

Plants with increased activity of a Class 3 branching enzyme

Description

[001] The present invention relates to plant cells and plants, which are genetically modified, wherein the genetic modification leads to an increase in the activity of a Class 3 vegetable branching enzyme in comparison with corresponding wild type plant cells or wild type plants that have not been genetically modified. Furthermore, the present invention relates to means and methods for the manufacture of such plant cells and plants. Plant cells and plants of this type synthesise a modified starch. The present invention therefore also relates to the starch synthesised by the plant cells and plants according to the invention as well as to methods for the manufacture of the starch and to the manufacture of starch derivatives of this modified starch.

[002] With regard to the increasing importance currently attributed to vegetable constituents as renewable raw material sources, one of the tasks of biotechnological research is to endeavour to adapt these vegetable raw materials to suit the requirements of the processing industry. Furthermore, in order to enable regenerating raw materials to be used in as many areas of application as possible, it is necessary to achieve a large variety of materials.

[003] Polysaccharide starch is made up of chemically uniform base components, the glucose molecules, but constitutes a complex mixture of different molecule forms, which exhibit differences with regard to the degree of polymerisation and branching, and therefore differ strongly from one another in their physical-chemical characteristics. Discrimination is made between amylose starch, an essentially unbranched polymer made from α -1,4-glycosidically linked glucose units, and the amylopectin starch, a branched polymer, in which the branches come about by the occurrence of additional α -1,6-glycosidic links. A further essential difference between amylose and amylopectin lies in the molecular weight. While amylose, depending on the origin of the starch, has a molecular weight of $5 \times 10^5 - 10^6$ Da, that of the amylopectin lies between 10^7 and 10^8 Da. The two macromolecules can be differentiated by their molecular

weight and their different physical-chemical characteristics, which can most easily be made visible by their different iodine bonding characteristics.

[004] Amylose has long been looked upon as a linear polymer, consisting of α -1,4-glycosidically linked α -D-glucose monomers. In more recent studies, however, the presence of α -1,6-glycosidic branching points (ca. 0.1%) has been shown (Hizukuri and Takagi, Carbohydr. Res. 134, (1984), 1-10; Takeda et al., Carbohydr. Res. 132, (1984), 83-92).

[005] Amylopectin constitutes a complex mixture of differently branched glucose chains. In contrast to amylose, amylopectin is more strongly branched. According to textbook information (Voet and Voet, Biochemistry, John Wiley & Sons, 1990), on average, the α -1,6 branches occur every 24 to 30 glucose residues. This is equivalent to a degree of branching of ca. 3% - 4%. The figures for the degree of branching are variable and are dependent on the origin (e.g. plant species, plant type etc.) of the appropriate starch. In typical plants used for the industrial production of starch, such as maize, wheat or potato, for example, the synthesised starch consists of ca. 20% - 30% amylose starch and ca. 70% - 80% amylopectin starch.

[006] The functional characteristics of the starch, along with the amylose/amylopectin ratio and the phosphate content, are strongly affected by the molecular weight, the pattern of the side chain distribution, the ion concentration, the lipid and protein content, the average grain size of the starch and the grain morphology of the starch etc. At the same time, by way of example, the solubility, the retrogradation behaviour, the water bonding capability, the film formation characteristics, the viscosity, the sticking characteristics, the freezing-thawing stability, the acid stability, the gelling strength etc. must be mentioned as important functional characteristics. The grain size of the starch can also be important for different applications.

[007] Branching enzymes, which are also abbreviated by the designation "BE" (from Branching Enzyme; E.C. 2.4.1.18), catalyse the introduction of α -1,6 branches in α -1,4-glucans. Branching enzymes and the nucleic or amino acid sequences that characterise them are known from widely different organisms, such as bacteria, microbial fungi, mammals, algae and higher plants, for example. As only plants synthesise starch, while the above-mentioned non-vegetable

organisms (e.g. bacteria, fungi and mammals) synthesise glycogen, the related branching enzymes, which are involved in the synthesis of the appropriate polymer, can also be sub-divided into glycogen branching enzymes and starch branching enzymes. Plants are therefore starch branching enzymes, which are often also referred to as Q-enzymes in older literature.

[008] In all plant species that have been investigated up to now, the branching enzymes described can be associated with two different classes (Burton et al., 1995, Plant Journal 7, 3-15; Mizuno et al., 2001, Plant Cell Physiol. 42(4), 349-357). The association with these classes, sometimes designated in the literature with A or 2 respectively and B or 1 respectively, is based on the comparison of derived protein sequences.

[009] As different nomenclatures have been used in the past for designating and classifying branching enzymes, Smith-White and Preiss (1994, Plant Molecular Biology Reporter 12, 67-71) (1994, Plant Molecular Biology Reporter 12, 67-71) have proposed a system for standardising this nomenclature, in which the association with the two classes of vegetable branching enzymes is also based on the comparison of derived protein sequences (Larsson et al., 1998, Plant Mol. Biol. 37, 505-511). According to this nomenclature, those vegetable branching enzymes, the amino acid sequence of which has a higher degree of identity with that of branching enzyme I of maize (GenBank Acc: D11081), is to be designated as a Class 1 branching enzyme, and those vegetable branching enzymes, the coding amino acid sequence of which has a higher degree of identity with that of branching enzyme II of maize (GenBank Acc: AF072725), is to be designated as a Class 2 branching enzyme. The designation of gene products, which are coding for branching enzymes, are, in accordance with the nomenclature of Smith-White and Preiss, to be incorporated in the already existing nomenclature by means of E.C. numbers. This results in the so-called GPN (Gene Product Number) Codes for the two classes, namely GPN 2.2.4.1.18:1 for Class 1 branching enzymes and GPN 2.2.4.18:2 for Class 2 branching enzymes.

[0010] The following vegetable or starch branching enzymes therefore belong to Class 1 (GPN 2.2.1.18:1) according to the nomenclature proposed by Smith-White and Preiss (1994, Plant Molecular Biology Reporter 12, 67-71): BE I from *Aegilops tauschii* (GenBank Acc: AF525746), BE I from barley (GenBank Acc: AY304541), BE from tapioca (GenBank Acc:

X77012), BE I (frequently also described as BE 1) from rice (GenBank Acc: D11082, D10752, D10838), BE 3 from bean (GenBank Acc: AB029549), BE II from pea (GenBank Acc: X80010), BE from millet (GenBank Acc: AF169833), BE I from potato (GenBank Acc: Y08786, X69805), BE from wheat (GenBank Acc: Y12320, AF076679, AF002820) and BE I from maize (GenBank Acc: D11081, AAO20100, E03435, AY176762, U17897, AF072724). At the same time, the amino acid sequences for different Class 1 branching enzymes each have an identity of more than 60% with the amino acid sequence of branching enzyme I from maize (GenBank Acc: D11081).

[0011] Branching enzymes, which belong to Class 2 (GPN 2.2.1.18:2) according to the nomenclature proposed by Smith-White and Preiss (1994, Plant Molecular Biology Reporter 12, 67-71) are, for example, BE IIa from *Aegilops tauschii* (GenBank Acc: AF338431, WO 9914314), BE2-1 and BE2-2 from *Arabidopsis thaliana* (BE2-1 GenBank Acc: NM_129196 CAA04134; BE2-2 GenBank Acc: CAB82930, NM_120446), BE IIa and BE IIb from barley (BE IIa GenBank Acc: AF064560; BE IIb GenBank Acc: AF064561), BE II from sweet potato (GenBank Acc: AB071286), BE III and BE IV (frequently also described as BE 3 or BE 4 respectively) from rice (BE III GenBank Acc: D16201; BE IV GenBank Acc: AB023498), BE 1 from bean (GenBank Acc: AB029548), BE I from pea (GenBank Acc: X80009), BE IIb from millet (GenBank Acc: AY304540), BE II from potato (GenBank Acc: AJ000004, AJ011885, AJ011888, AJ011889, AJ011890), BE II or BE IIa from wheat (GenBank Acc: Y11282, AF286319, AF338432, U66376) and BE II, or BE IIb from maize (BE II GenBank Acc: AAA18571, T02981; BE IIb GenBank Acc: AF072725, L08065). At the same time, the amino acid sequences for different Class 2 branching enzymes each have an identity of more than 60% with the amino acid sequence of branching enzyme IIb from maize (GenBank Acc: AF072725).

[0012] Vegetable or starch branching enzymes belong to the family of alpha-amylolytic enzymes (Svensson, 1994, Plant Molecular Biology 25, 141-157; Jespersen et al., 1991, Biochem J. 280, 51-55) and, with regard to the amino acid sequence, have four conserved domains (Baba et al., 1991, Biochem. Biophys. Res. Commun. 181(1), 87-94; Kuriki et al., 1996, J. of Protein Chemistry 15(3), 305-313).

[0013] Structural predictions based on mathematical calculations derived from experimental

data such as protein crystal structures (Pfam: <http://hits.isb-sib.ch/cgi-bin/PFSCAN?>) show that all previously known branching enzymes from higher plants have two domains: an alpha-amylase domain and an iso-amylase domain. Here, the iso-amylase domain lies closer to the N-terminus of the protein than the alpha-amylase domain.

[0014] Plants are known, for example, which have a reduced activity of a Class 2 branching enzyme due to a mutation. These include the so-called "*amylose extender*" (*ae*) mutants from maize (Stindard et al., 1993, Plant Cell 5, 1555-1566; Boyer and Preiss, 1978, Biochem. Biophys. Res. Commun. 80, 169-175) and rice (Mizuno et al., 1993, J. Biol. Chem. 268, 19084-19091), as well as the "*rugosus*" (*r*) mutation in pea (Smith, 1988, Planta 175, 270-279; Bhattacharyya et al., 1990, Cell 60, 115-122). All these mutants are distinguished by the fact that they synthesise a starch, which has an increased amylose content in comparison with starches from corresponding plants, which do not have this mutation.

[0015] Furthermore, genetically modified potato plants are described, in which the activity of a BE I (Class 1) branching enzyme (Kossmann et al., 1991, Mol Gen Genet 230, 39-44; Safford et al., 1998, Carbohydrate Polymers 35, 155-168), or the activity of a BEII (Class 2) branching enzyme (Jobling et al., 1999, The Plant Journal 18), or the activity of a BEI and BEII branching enzyme (Schwall et al., 2000, Nature Biotechnology 18, 551- 554, Jobling et al., 2003, Nature Biotechnology 21, 77-80) are reduced.

[0016] Previously, it has been possible to associate all vegetable branching enzymes to one or both of the classes described above. Plant cells or plants, which have an increased activity of a branching enzyme, which cannot be associated with these classes, are unknown.

[0017] The object of the present invention is therefore based on providing modified starches, new plant cells and/or plants, which synthesise such a modified starch, as well as methods for producing said plants.

[0018] This problem is solved by the embodiments described in the claims.

[0019] The present invention therefore relates to genetically modified plant cells and plants, characterised in that the plant cells or plants have an increased activity of at least one Class 3 branching enzyme in comparison with corresponding wild type plant cells or wild type plants that have not been genetically modified.

[0020] A first aspect of the present invention relates to a plant cell or plant, which is genetically modified, wherein the genetic modification leads to an increase in the activity of at least one Class 3 branching enzyme in comparison with corresponding wild type plant cells or wild type plants that have not been genetically modified.

[0021] At the same time, the genetic modification can be any genetic modification, which leads to an increase in the activity of at least one Class 3 branching enzyme in comparison with corresponding wild type plant cells or wild type plants that have not been genetically modified.

[0022] In conjunction with the present invention, the term "wild type plant cell" means that the plant cells concerned were used as starting material for the manufacture of the plant cells according to the invention, i.e. their genetic information, apart from the introduced genetic modification, corresponds to that of a plant cell according to the invention.

[0023] In conjunction with the present invention, the term "wild type plant" means that the plants concerned were used as starting material for the manufacture of the plants according to the invention, i.e. their genetic information, apart from the introduced genetic modification, corresponds to that of a plant according to the invention.

[0024] In conjunction with the present invention, the term "corresponding" means that, in the comparison of several objects, the objects concerned that are compared with one another have been kept under the same conditions. In conjunction with the present invention, the term "corresponding" in conjunction with wild type plant cell or wild type plant means that the plant cells or plants, which are compared with one another, have been raised under the same cultivation conditions and that they have the same (cultivation) age.

[0025] The plant cells according to the invention have an increased activity of at least one Class 3 branching enzyme in comparison with corresponding wild type plant cells that have not been genetically modified.

[0026] Here, within the framework of the present invention, the term "increased activity" means an increase in the expression of endogenous genes, which code Class 3 branching enzymes and/or an increase in the quantity of Class 3 branching enzyme protein in the cells and/or an increase in the enzymatic activity of Class 3 branching enzymes in the cells.

[0027] The increase in the expression can, for example, be determined by measuring the quantity of transcripts coding Class 3 branching enzyme, e.g. using Northern blot analysis or RT-PCR. Here, an increase preferably means an increase in the amount of transcripts in comparison with corresponding cells that have not been genetically modified by at least 50%, in particular by at least 70%, preferably by at least 85% and particularly preferably by at least 100%.

[0028] The increase in the amount of protein of a Class 3 branching enzyme, which results in an increased activity of this protein in the plant cells concerned, can, for example, be determined by immunological methods such as Western blot analysis, ELISA (Enzyme Linked Immuno Sorbent Assay) or RIA (Radio Immune Assay). Here, an increase preferably means an increase in the amount of Class 3 branching enzyme protein in comparison with corresponding cells that have not been genetically modified by at least 50%, in particular by at least 70%, preferably by at least 85% and particularly preferably by at least 100%.

[0029] Within the framework of the present invention, the term "branching enzyme" (α -1,4-glucan: α -1,4-glucan 6-glycosyltransferase, E.C. 2.4.1.18) is understood to mean a protein, which catalyses a transglycosylation reaction, in which α -1,4 links of an α -1,4-glucan donor are hydrolysed and the thereby released α -1,4-glucan chains are transferred to an α -1,4-glucan acceptor chain and, in doing so, are transformed into α -1,6-links. In particular, within the framework of the present invention, the term "branching enzyme" is to be understood to mean a vegetable branching enzyme, i.e. a starch branching enzyme.

[0030] The activity of a branching enzyme can be demonstrated, for example, with the help of native acrylamide gel electrophoresis. In doing so, proteins are first separated electrophoretically and, after incubation in buffers containing an activity, which synthesises linear α -1,4-glucan chains (e.g. starch phosphorylase a) and its substrate (e.g. glucose-6-phosphate), the corresponding gels are coloured with iodine (Kimihiro et al., 1980, Analytical Biochemistry 108, 16-24). Furthermore, branching enzymes in microbial organisms, such as the *E. coli* strain KV832 for example (Kiel et al., 1987 Mol. Gen. Genet 207: 294-301), which do not synthesise branched α -glucans, can be expressed. If an activity of a branching enzyme is introduced into the microbial organism due to the expression of a foreign gene in such strains (e.g. *E. coli* KV832), then the branching enzyme activity can be demonstrated by treating colonies of these organisms with iodine vapour, for example. Colonies, which synthesise linear α -1,4-glucans, turn blue in this test, while colonies, which synthesise branched glucans by expressing an additional enzymatic activity of a branching enzyme, turn reddish-brown after treating with iodine vapour. It is also possible to express proteins in phosphoglucomutase mutants of *E. coli* to identify a branching enzyme activity of appropriate proteins (Buettcher et al., 1999, Biochem. Biophys. Acta 1432, 406-412).

[0031] A further possibility of demonstrating branching enzyme activity of proteins is the use of a reaction stimulated by phosphorylase a and the subsequent separation of the products by means of thin film chromatography (Almstrupp et al., 2000, Analytical Biochemistry 286, 297-300). Branching enzyme activities can also be demonstrated with the help of the methods described in Guan and Preiss (1993, Plant Physiol. 102, 1269-1273) and Kuriki et al. (1996, J. of Protein Chemistry 15, 305-313).

[0032] In conjunction with the present invention, the term "Class 3 branching enzyme" is to be understood as a branching enzyme, which has a higher degree of identity with the amino acid sequence specified in Seq ID NO 4 than with that of the branching enzyme BE I from maize (GenBank Acc: D11081) or with that of the branching enzyme BE IIb from maize (GenBank Acc: AF072725). Preferably, the Class 3 branching enzyme comes from starch-storing plants, particularly preferably from plant species of the genus *Solanum*, especially preferably from *Solanum tuberosum*.

[0033] In a further embodiment of the present invention, amino acid sequences coding Class 3 branching enzymes have an identity of at least 60% with the sequence specified in SEQ ID NO 4, in particular of at least 70%, preferably of at least 80% and particularly preferably of at least 90% and especially preferably of at least 95%.

[0034] According to the invention, Class 3 branching enzymes have an iso-amylase domain (Pfam acc.: Pf02922) and an alpha-amylase domain (Pfam acc: Pf00128). According to the invention, the iso-amylase domain and the alpha-amylase domain in amino acid sequences coding branching enzymes are separated from one another by the presence of further amino acids, which do not belong to these two domains.

[0035] Class 3 branching enzymes according to the invention are distinguished by the fact that the iso-amylase domain is separated from the alpha-amylase domain by a greater number of amino acids than the iso-amylase domain and the alpha-amylase domain of Class 1 and 2 branching enzymes.

[0036] Class 3 branching enzymes according to the invention are preferably distinguished with regard to their amino acid sequence by the fact that they have at least 70, preferably at least 100, particularly preferably at least 130 and especially preferably at least 198 amino acids between the iso-amylase domain and the alpha-amylase domain. In a further embodiment of the present invention, in the case of an amino acid sequence coding a Class 3 branching enzyme, the C-terminal end of the iso-amylase domain is separated from the N-terminal beginning of the alpha-amylase domain by 70 to 198, preferably by 100 to 198, particularly preferably by 130 to 198 and especially particularly preferably by 150 to 198 amino acids.

[0037] With the help of the Pfam database (Batemann et al., 2002, Nucleic Acids Research 30, 276-280; accessible via <http://www.sanger.ac.uk/Software/Pfam/>, <http://www.cgb.ki.se/Pfam/>; <http://pfam.jouy.inra.fr/> or <http://pfam.wustl.edu/>), it is possible for the person skilled in the art to determine whether amino acid sequences already have known domains (e.g. an iso-amylase domain and/or an alpha-amylase domain). Pfam is a database put

together by experts, which classifies amino acid sequences into so-called families. Here, the assignment of an amino acid sequence to a family is carried out on the basis of so-called domains, which are to be looked upon as functional and structural components of proteins. A domain is defined as a structural unit or a repeatedly occurring amino acid sequence unit, which can occur in proteins with widely different functions. Along with information relating to the amino acid sequence of known proteins, further knowledge (e.g. evidence of the enzymatic activity, crystal structure data) is also used for the assignment of a protein to a family. Each family is assigned a name and an "accession" number (e.g. Name: Isoamylase_N, acc: PF02922). A constituent part of each family in the Pfam database is, amongst other things, a so-called "seed alignment". The "seed alignment" contains the amino acid sequences of representative proteins of a family. Starting from "seed alignments", a so-called profile HMM ("profile Hidden Markov Model"; overview article in: Durbin et al., "Biological Sequence Analysis: Probabilistic Models of Proteins and Nucleic Acids", Cambridge University Press, 1998, ISBN 0-521-62041-4) is produced using the HMMER 2 software (freely available under <http://hmmer.wustl.edu/>). The HMMs produced have names and are stored in the Pfam database specifically for the correspondingly assigned domains. In contrast to classical, multiple "alignments" (e.g. produced using the Clustal W program or the Blossum62 algorithm), HMMs are based on a valid statistical theory (Bayes theory of conditional probability, Markoff chains) and enable an interrogation sequence (query) to be assigned to a family based on the use of position-specific evaluation matrices. This enables an assignment to be made even when there are considerable differences in the amino acid sequences between the interrogation sequence (Query) and a comparison sequence (e.g. amino acid sequence entry in a database).

[0038] The domain structure of the amino acid sequence concerned can be determined by means of a comparison of the HMMs stored in the Pfam database with amino acid sequences, which are entered as a so-called interrogation sequence (query) (e.g. under <http://hits.isb-sib.ch/cgi-bin/PFSCAN?>).

[0039] In conjunction with the present invention, the term "iso-amylase domain" is to be understood to mean a Pfam iso-amylase domain (acc: Pf02922). At the same time, the HMM describing this Pfam iso-amylase domain is to be produced with the HMMER 2 [2.3.1] software,

starting from a "seed alignment", which contains the amino acid sequences shown in Table 1. In conjunction with the present invention, the "seed alignment" is produced by means of the ClustalW program (Thompson et al., Nucleic Acids Research 22 (1994), 4673-4680; see below). The following settings must be chosen to produce the appropriate HMMs: Build Method of HMM: hmmbuild -F HMM_ls, hmmcalibrate -seed 0 HMM_ls; Gathering cutoff: 2.3 2.3; Trusted cutoff: 2.3 2.2; Noise cutoff: 2.1 2.1). Further information for producing the HMM of the Pfam iso-amylase domain (acc: Pf02922) is given in Table 3.

[0040] In conjunction with the present invention, the term "alpha-amylase domain" is to be understood to mean a Pfam alpha-amylase domain (acc: Pf00128). At the same time, the HMM describing this Pfam alpha-amylase domain is to be produced with the HMMER 2 [2.3.1] software, starting from a "seed alignment", which contains the amino acid sequences shown in Table 2. Here, the "seed alignment" is produced by means of HMM_simulated_annealing (<http://www.psc.edu/general/software/packages/hmmer/manual/node11.html#SECTION00321000000000000000>). The following settings must be chosen to produce the appropriate HMM: Build Method of HMM: hmmbuild -F HMM_ls, hmmcalibrate -seed 0 HMM_ls; Gathering cutoff: -82.0 -82.0; Trusted cutoff: -81.7 -81.7; Noise cutoff: -82.7 -82.7). Further information for producing the HMM of the Pfam alpha-amylase domain (acc: Pf00128) is given in Table 4.

[0041] In conjunction with the present invention, the term "Class 3 branching enzyme gene" is to be understood to mean a nucleic acid molecule (cDNA, DNA), which codes a Class 3 branching enzyme, preferably a Class 3 branching enzyme from starch-storing plants, particularly preferably from plant species of the genus *Solanum*, especially preferably from *Solanum tuberosum*.

[0042] A preferred embodiment of the present invention relates to a genetically modified plant cell according to the invention or a genetically modified plant according to the invention, wherein the genetic modification consists in the introduction of at least one foreign nucleic acid molecule into the genome of the plant cell or into the genome of the plant.

[0043] In this context, the term "genetic modification" means the introduction of homologous

and/or heterologous foreign nucleic acid molecules into the genome of a plant cell or into the genome of a plant, wherein said introduction of these molecules leads to an increase in the activity of a Class 3 branching enzyme.

[0044] The plant cells according to the invention or plants according to the invention are modified with regard to their genetic information by the introduction of a foreign nucleic acid molecule. The presence or the expression of the foreign nucleic acid molecule leads to a phenotypic change. Here, "phenotypic" change means preferably a measurable change of one or more functions of the cells. For example, the genetically modified plant cells according to the invention and the genetically modified plants according to the invention exhibit an increase in the activity of a Class 3 branching enzyme due to the presence or on the expression of the introduced nucleic acid molecule.

[0045] In conjunction with the present invention, the term "foreign nucleic acid molecule" is understood to mean such a molecule that either does not occur naturally in the corresponding wild type plant cells, or that does not occur naturally in the concrete spatial arrangement in wild type plant cells, or that is localised at a place in the genome of the wild type plant cell at which it does not occur naturally. Preferably, the foreign nucleic acid molecule is a recombinant molecule, which consists of different elements, the combination or specific spatial arrangement of which does not occur naturally in vegetable cells. In principle, the foreign nucleic acid molecule can be any nucleic acid molecule, which effects an increase in the activity of a Class 3 branching enzyme in the plant cell or plant.

[0046] In conjunction with the present invention, the term "genome" is to be understood to mean the totality of the genetic material present in a vegetable cell. It is known to the person skilled in the art that, as well as the cell nucleus, other compartments (e.g. plastids, mitochondrions) also contain genetic material.

[0047] In a further embodiment, the plant cells according to the invention and the plants according to the invention are characterised in that the foreign nucleic acid molecule codes a Class 3 branching enzyme, preferably a Class 3 branching enzyme from starch-storing plants,

particularly preferably from plants of a species of the genus *Solanum*, especially preferably from *Solanum tuberosum*.

[0048] In a particularly preferred embodiment, the foreign nucleic acid molecule codes a Class 3 branching enzyme with the amino acid sequence specified in SEQ ID NO 4.

[0049] A large number of techniques are available for the introduction of DNA into a vegetable host cell. These techniques include the transformation of vegetable cells with T-DNA using *Agrobacterium tumefaciens* or *Agrobacterium rhizogenes* as the transformation medium, the fusion of protoplasts, injection, the electroporation of DNA, the introduction of DNA by means of the biolistic approach as well as other possibilities. The use of agrobacteria-mediated transformation of plant cells has been intensively investigated and adequately described in EP 120516; Hoekema, IN: The Binary Plant Vector System Offsetdrukkerij Kanters B.V., Alblasterdam (1985), Chapter V; Fraley et al., Crit. Rev. Plant Sci. 4, 1-46 and by An et al. EMBO J. 4, (1985), 277-287. For the transformation of potato, see Rocha-Sosa et al., EMBO J. 8, (1989), 29-33, for example.

[0050] The transformation of monocotyledonous plants by means of vectors based on agrobacterium transformation has also been described (Chan et al., Plant Mol. Biol. 22, (1993), 491-506; Hiei et al., Plant J. 6, (1994) 271-282; Deng et al, Science in China 33, (1990), 28-34; Wilmink et al., Plant Cell Reports 11, (1992), 76-80; May et al., Bio/Technology 13, (1995), 486-492; Conner and Domisse, Int. J. Plant Sci. 153 (1992), 550-555; Ritchie et al, Transgenic Res. 2, (1993), 252-265). An alternative system to the transformation of monocotyledonous plants is transformation by means of the biolistic approach (Wan and Lemaux, Plant Physiol. 104, (1994), 37-48; Vasil et al., Bio/Technology 11 (1993), 1553-1558; Ritala et al., Plant Mol. Biol. 24, (1994), 317-325; Spencer et al., Theor. Appl. Genet. 79, (1990), 625-631), protoplast transformation, electroporation of partially permeabilised cells and the introduction of DNA by means of glass fibres. In particular, the transformation of maize has been described in the literature many times (cf. e.g. WO95/06128, EP0513849, EP0465875, EP0292435; Fromm et al., Biotechnology 8, (1990), 833-844; Gordon-Kamm et al., Plant Cell 2, (1990), 603-618; Koziel et al., Biotechnology 11 (1993), 194-200; Moroc et al., Theor. Appl. Genet. 80, (1990), 721-726).

[0051] The successful transformation of other types of cereal has also already been described, for example for barley (Wan and Lemaux, see above; Ritala et al., see above; Krens et al., Nature 296, (1982), 72-74) and for wheat (Nehra et al., Plant J. 5, (1994), 285-297). All the above methods are suitable within the framework of the present invention.

[0052] Amongst other things, the plant cells according to the invention and the plants according to the invention can be differentiated from wild type plant cells and wild type plants respectively in that they contain a foreign nucleic acid molecule, which does not occur naturally in wild type plant cells or wild type plants, or in that such a molecule is present integrated at a place in the genome of the plant cell according to the invention or in the genome of the plant according to the invention at which it does not occur in wild type plant cells or wild type plants, i.e. in a different genomic environment. Furthermore, plant cells according to the invention and plants according to the invention of this type differ from wild type plant cells and wild type plants respectively in that they contain at least one copy of the foreign nucleic acid molecule stably integrated within their genome, possibly in addition to naturally occurring copies of such a molecule in the wild type plant cells or wild type plants. If the foreign nucleic acid molecule(s) introduced into the plant cells according to the invention or into the plants according to the invention is (are) additional copies of molecules already occurring naturally in the wild type plant cells or wild type plants respectively, then the plant cells according to the invention and the plants according to the invention can be differentiated from wild type plant cells or wild type plants respectively in particular in that this additional copy or these additional copies is (are) localised at places in the genome at which it does not occur (or they do not occur) in wild type plant cells or wild type plants. This can be verified, for example, with the help of a Southern Blot Analysis.

[0053] Furthermore, the plant cells according to the invention and the plants according to the invention can preferably be differentiated from wild type plant cells or wild type plants respectively by at least one of the following characteristics: If the foreign nucleic acid module that has been introduced is heterologous with respect to the plant cell or plant, then the plant cells according to the invention or plants according to the invention have transcripts of the introduced nucleic acid molecules. These can be verified, for example, by Northern blot analysis or by RT-

PCR (Reverse Transcription Polymerase Chain Reaction). Plant cells according to the invention and plants according to the invention, which express an antisense and/or an RNAi transcript, can be verified, for example, with the help of specific nucleic acid probes, which are complimentary to the RNA (occurring naturally in the plant cell), which is coding for the protein. Preferably, the plant cells according to the invention and the plants according to the invention contain a protein, which is coded by an introduced nucleic acid molecule. This can be demonstrated by immunological methods, for example, in particular by a Western Blot Analysis.

[0054] If the foreign nucleic acid module that has been introduced is homologous with respect to the plant cell or plant, the plant cells according to the invention or plants according to the invention can be differentiated from wild type plant cells or wild type plants respectively due to the additional expression of the introduced foreign nucleic acid molecule, for example. The plant cells according to the invention and the plants according to the invention preferably contain (sense and/or antisense) transcripts of the foreign nucleic acid molecules. This can be demonstrated by Northern blot analysis, for example, or with the help of so-called quantitative PCR.

[0055] In a special embodiment, the plant cells according to the invention and the plants according to the invention are transgenic plant cells or transgenic plants respectively

[0056] In a further embodiment, the present invention relates to plant cells according to the invention and plants according to the invention wherein the foreign nucleic acid molecule is chosen from the group consisting of

- a) Nucleic acid molecules, which code a protein with the amino acid sequence given under Seq ID NO 4;
- b) Nucleic acid molecules, which code a protein, the amino acid sequence of which has an identity of at least 50% with the amino acid sequence given under SEQ ID NO: 4;
- c) Nucleic acid molecules, which include the nucleotide sequence shown under Seq ID NO 3 or a complimentary sequence;
- d) Nucleic acid molecules, the nucleic acid sequence of which has an identity of at least 50% with the nucleic acid sequences described under a) or c);

- e) Nucleic acid molecules, which hybridise with at least one strand of the nucleic acid molecules described under a) or c) under stringent conditions;
- f) Nucleic acid molecules, the nucleotide sequence of which deviates from the sequence of the nucleic acid molecules identified under a), b), c), d), e) or f) due to the degeneration of the genetic code; and
- g) Nucleic acid molecules, which represent fragments, allelic variants and/or derivatives of the nucleic acid molecules identified under a), b), c), d), e) or f).

[0057] The amino acid sequence specified in SEQ ID NO 4 codes a protein with the activity of a Class 3 branching enzyme from *Solanum tuberosum*.

[0058] A plasmid was deposited with the Deutsche Sammlung von Mikroorganismen und Zellkulturen GmbH, Mascheroder Weg 1b, 38124 Braunschweig, Germany, in accordance with the Budapest Treaty on 15th September 2003 under the number DSM 15926. The amino acid sequence shown SEQ ID NO 4 can be derived from the coding region of the cDNA sequence integrated in plasmid DSM 15926 and codes for a Class 3 branching enzyme from *Solanum tuberosum*. The present invention relates to nucleic acid molecules, which code a protein with the enzymatic activity of a Class 3 branching enzyme, which includes the amino acid sequence, which is coded by the insertion in plasmid DSM 15926, wherein the coded protein has an identity of at least 70%, preferably of at least 80%, particularly preferably of at least 90% and especially preferably of 95% with the amino acid sequence, which can be derived from the insertion coding a Class 3 branching enzyme in DSM 15926.

[0059] The proteins coded from the different varieties of nucleic acid molecules according to the invention have certain common characteristics. These can include, for example, biological activity, molecular weight, immunological reactivity, conformation, the presence of structural and/or functional domains etc, as well as physical characteristics such as, for example, the running behaviour in gel electrophoresis, chromatographic behaviour, sedimentation coefficients, solubility, spectroscopic characteristics, stability; optimum pH, optimum temperature etc.

[0060] The molecular weight of the Class 3 branching enzyme from *Solanum tuberosum*

derived from the amino acid sequence shown under SEQ ID NO 4 is ca. 103 kDa. The derived molecular weight of a protein according to the invention therefore preferably lies in the range from 85 kDa to 120 kDa, preferably in the range from 95 kDa to 110 kDa and particularly preferably from ca. kDa 100 to 105 kDa.

[0061] The nucleic acid sequence shown in SEQ ID NO 3 is a cDNA sequence, which includes the coding region for a Class 3 branching enzyme from *Solanum tuberosum*.

[0062] The present invention therefore also relates to nucleic acid molecules, which code a Class 3 branching enzyme and the coding region of the nucleotide sequence shown under Seq ID NO 3 or a complimentary sequence, nucleic acid molecules, which include the coding region of the nucleotide sequence of the insertion contained in plasmid DSM 15926, and nucleic acid molecules, which have an identity of at least 70%, preferably of at least 80%, particularly preferably of at least 90% and especially preferably of at least 95% with the said nucleic acid molecules.

[0063] With the help of the sequence information of the nucleic acid molecule according to the invention or with the help of the nucleic acid molecule according to the invention, it is now possible for the person skilled in the art to isolate homologous sequences from other plant species, preferably from starch-storing plants, preferably from plant species of the genus *Solanum*, particularly preferably from *Solanum tuberosum*. This can be carried out, for example, with the help of conventional methods such as the examination of cDNA or genomic banks with suitable hybridisation samples. The person skilled in the art knows that homologous sequences can also be isolated with the help of (degenerated) oligonucleotides and the use of PCR-based methods.

[0064] The examination of databases, such as are made available, for example, by EMBL (<http://www.ebi.ac.uk/Tools/index.htm>) or NCBI (National Center for Biotechnology Information, <http://www.ncbi.nlm.nih.gov/>), can also be used for identifying homologous sequences, which code for a Class 3 branching enzyme. In this case, one or more sequences are specified as a so-called query. This query sequence is then compared by means of statistical

computer programs with sequences, which are contained in the selected databases. Such database queries (e.g. blast or fasta searches) are known to the person skilled in the art and can be carried out by various providers. If such a database query is carried out, e.g. at the NCBI (National Center for Biotechnology Information, <http://www.ncbi.nlm.nih.gov/>), then the standard settings, which are specified for the particular comparison inquiry, should be used. For protein sequence comparisons (blastp), these are the following settings: Limit entrez = not activated; Filter = low complexity activated; Expect value = 10; word size = 3; Matrix = BLOSUM62; Gap costs: Existence = 11, Extension = 1.

[0065] For nucleic acid sequence comparisons (blastn), the following parameters must be set: Limit entrez = not activated; Filter = low complexity activated; Expect value = 10; word size = 11.

[0066] With such a database search, the sequences described in the present invention can be used as a query sequence in order to identify further nucleic acid molecules and/or proteins, which code a Class 3 branching enzyme.

[0067] With the help of the described methods, it is also possible to identify and/or isolate nucleic acid molecules according to the invention, which hybridise with the sequence specified under SEQ ID NO: 3 and which code a Class 3 branching enzyme.

[0068] Within the framework of the present invention, the term "hybridising" means hybridisation under conventional hybridisation conditions, preferably under stringent conditions such as, for example, are described in Sambrook et al., Molecular Cloning, A Laboratory Manual, 2nd Ed. (1989) Cold Spring Harbor Laboratory Press, Cold Spring Harbor, NY). Particularly preferably, "hybridising" means hybridisation under the following conditions:

[0069] Hybridisation buffer: 2xSSC; 10xDenhardt solution (Ficoll 400+PEG+BSA; Ratio 1:1:1); 0.1% SDS; 5 mM EDTA; 50 mM Na₂HPO₄; 250 µg/ml herring sperm DNA; 50 µg/ml tRNA; or 25 M sodium phosphate buffer pH 7.2; 1 mM EDTA; 7% SDS

[0070] Hybridisation temperature: T=65 to 68°C

[0071] Wash buffer: 0.2xSSC; 0.1% SDS

[0072] Wash temperature: T=65 to 68°C.

[0073] In principle, nucleic acid molecules, which hybridise with the nucleic acid molecules according to the invention, can originate from any plant species, which expresses an appropriate protein, preferably they originate from starch-storing plants, preferably from species of the genus *Solanum*, particularly preferably from *Solanum tuberosum*. Nucleic acid molecules, which hybridise with the molecules according to the invention, can, for example, be isolated from genomic or from cDNA libraries. The identification and isolation of nuclear acid molecules of this type can be carried out using the nucleic acid molecules according to the invention or parts of these molecules or the reverse complements of these molecules, e.g. by means of hybridisation according to standard methods (see, for example, Sambrook et al., 1989, Molecular Cloning, A Laboratory Manual, 2nd Ed. Cold Spring Harbor Laboratory Press, Cold Spring Harbor, NY) or by amplification using PCR.

[0074] Nucleic acid molecules, which exactly or essentially have the nucleotide sequence specified under SEQ ID NO: 3, or parts of this sequence, can be used as hybridisation samples. The fragments used as hybridisation samples can also be synthetic fragments or oligonucleotides, which have been manufactured using established synthesising techniques and the sequence of which corresponds essentially with that of a nucleic acid molecule according to the invention. If genes have been identified and isolated, which hybridise with the nucleic acid sequences according to the invention, then a determination of this sequence and an analysis of the characteristics of the proteins coded by this sequence should be carried out in order to establish whether a Class 3 branching enzyme is involved. Homology comparisons on the level of the nucleic acid or amino acid sequence and a determination of the enzymatic activity are particularly suitable for this purpose. As described above, the activity of a Class 3 branching enzyme can take place by expression in *E. coli* strains, which themselves do not express an active branching enzyme (Kiel et al., 1987 Mol. Gen. Genet 207: 294-301); Guan et al., 1995, Proc. Natl. Acad. Sci. 92, 964-967).

[0075] The molecules hybridising with the nucleic acid molecules according to the invention particularly include fragments, derivatives and allelic variants of the nucleic acid molecules described above, which code a Class 3 branching enzyme from plants, preferably from starch-storing plants, preferably from plant species of the genus *Solanum*, particularly preferably from *Solanum tuberosum*. In conjunction with the present invention, the term "derivative" means that the sequences of these molecules differ at one or more positions from the sequences of the nucleic acid molecules described above and have a high degree of identity with these sequences. Here, the deviation from the nucleic acid molecules described above can have come about, for example, due to deletion, addition, substitution, insertion or recombination.

[0076] The proteins coded from the different derivatives of nucleic acid molecules according to the invention have certain common characteristics. These can include, for example, biological activity, substrate specificity, molecular weight, immunological reactivity, conformation, the presence of structural and/or functional domains etc, as well as physical characteristics such as, for example, the running behaviour in gel electrophoresis, chromatographic behaviour, sedimentation coefficients, solubility, spectroscopic characteristics, stability; optimum pH, optimum temperature etc.

[0077] In conjunction with the present invention, the term "identity" means a sequence identity over the whole length of the coding region of at least 60%, in particular an identity of at least 70%, preferably greater than 80%, particularly preferably greater than 90% and especially of at least 95%. In conjunction with the present invention, the term "identity" is to be understood to mean the number of amino acids/nucleotides (identity) corresponding with other proteins/nucleic acids, expressed as a percentage. Identity is preferably determined by comparing the Seq. ID NO 4 or SEQ ID NO 3 with other proteins/nucleic acids with the help of computer programs. If sequences that are compared with one another have different lengths, the identity is to be determined in such a way that the number of amino acids, which have the shorter sequence in common with the longer sequence, determines the percentage quotient of the identity. Preferably, identity is determined by means of the computer program ClustalW, which is well known and available to the public (Thompson et al., Nucleic Acids Research 22 (1994), 4673-4680).

ClustalW is made publicly available by Julie Thompson (Thompson@EMBL-Heidelberg.DE) and Toby Gibson (Gibson@EMBL-Heidelberg.DE), European Molecular Biology Laboratory, Meyerhofstrasse 1, D 69117 Heidelberg, Germany. ClustalW can also be downloaded from different Internet sites, including the IGBMC (Institut de Génétique et de Biologie Moléculaire et Cellulaire, B.P.163, 67404 Illkirch Cedex, France; <ftp://ftp-igbmc.u-strasbg.fr/pub/>) and the EBI (<ftp://ftp.ebi.ac.uk/pub/software/>) as well as from all mirrored Internet sites of the EBI (European Bioinformatics Institute, Wellcome Trust Genome Campus, Hinxton, Cambridge CB10 1SD, UK).

[0078] Preferably, Version 1.8 of the ClustalW computer program is used to determine the identity between proteins according to the invention and other proteins. In doing so, the following parameters must be set: KTUPLE=1, TOPDIAG=5, WINDOW=5, PAIRGAP=3, GAOPEN=10, GAPEXTEND=0.05, GAPDIST=8, MAXDIV=40, MATRIX=GONNET, ENDGAPS(OFF), NOPGAP, NOHGAP.

[0079] Preferably, Version 1.8 of the ClustalW computer program is used to determine the identity between the nucleotide sequence of the nucleic acid molecules according to the invention, for example, and the nucleotide sequence of other nucleic acid molecules. In doing so, the following parameters must be set: KTUPLE=2, TOPDIAGS=4, PAIRGAP=5, DNAMATRIX:IUB, GAOPEN=10, GAPEXT=5, MAXDIV=40, TRANSITIONS: unweighted.

[0080] Furthermore, identity means that functional and/or structural equivalence exists between the nucleic acid molecules concerned or the proteins coded by them. The nucleic acid molecules, which are homologous to the molecules described above and constitute derivatives of these molecules, are generally variations of these molecules, which constitute modifications, which execute the same biological function. At the same time, the variations can occur naturally, for example they can be sequences from other plant species, or they can be mutations, wherein these mutations may have occurred in a natural manner or have been introduced by objective mutagenesis. The variations can also be synthetically manufactured sequences. The allelic variants can be both naturally occurring variants and also synthetically manufactured variants or variants produced by recombinant DNA techniques. Nucleic acid molecules, which deviate from

nucleic acid molecules according to the invention due to degeneration of the genetic code, constitute a special form of derivatives.

[0081] The nucleic acid molecules according to the invention can be any nucleic acid molecules, in particular DNA or RNA molecules, for example cDNA, genomic DNA, mRNA etc. They can be naturally occurring molecules or molecules manufactured by genetic or chemical synthesis methods. They can be single-stranded molecules, which either contain the coding or the non-coding strand, or double-stranded molecules.

[0082] Furthermore, the present invention relates to nucleic acid molecules of at least 21, preferably more than 50 and particularly preferably more than 200 nucleotides length, which specifically hybridise with at least one nucleic acid molecule according to the invention. Here, specifically hybridise means that these molecules hybridise with nucleic acid molecules, which code a protein according to the invention, but not with nucleic acid molecules, which code other proteins.

[0083] A further embodiment of the present invention relates to plant cells according to the invention and plants according to the invention wherein the foreign nucleic acid molecule is chosen from the group consisting of

- a) T-DNA molecules, which lead to an increase in the expression of a Class 3 branching enzyme gene due to integration in the vegetable genome (T-DNA activation tagging);
- b) DNA molecules, which contain transposons, which lead to an increase in the expression of a Class 3 branching enzyme gene due to integration in the vegetable genome (transposon activation tagging);
- c) DNA molecules, which code a Class 3 branching enzyme and which are linked with regulatory sequences, which guarantee transcription in vegetable cells and lead to an increase in Class 3 branching enzyme activity in the cell.
- d) Nucleic acid molecules introduced by means of in vivo mutagenesis, which lead to a mutation or an insertion of a heterologous sequence in at least one endogenous gene coding a Class 3 branching enzyme, wherein the mutation or insertion effects an increase in the expression of a gene coding a Class 3 branching enzyme.

[0084] In conjunction with the present invention, plant cells according to the invention and plants according to the invention can also be manufactured by the use of so-called insertion mutagenesis (overview article: Thorneycroft et al., 2001, Journal of experimental Botany 52 (361), 1593-1601). In conjunction with the present invention, insertion mutagenesis is to be understood to mean particularly the insertion of transposons or so-called transfer DNA (T-DNA) into a gene or in the vicinity of a gene coding for a Class 3 branching enzyme, whereby as a result of which the activity of a Class 3 branching enzyme in the cell concerned is increased.

[0085] The transposons can be both those that occur naturally in the cell (endogenous transposons) and also those that do not occur naturally in said cell but are introduced into the cell (heterologous transposons) by means of genetic engineering methods, such as transformation of the cell, for example. Changing the expression of genes by means of transposons is known to the person skilled in the art. An overview of the use of endogenous and heterologous transposons as tools in plant biotechnology is presented in Ramachandran and Sundaresan (2001, Plant Physiology and Biochemistry 39, 234-252).

[0086] T-DNA insertion mutagenesis is based on the fact that certain sections (T-DNA) of Ti plasmids from *Agrobacterium* can integrate into the genome of vegetable cells. The place of integration in the vegetable chromosome is not defined, but can take place at any point. If the T-DNA integrates into a part of the chromosome or in the vicinity of a part of the chromosome, which constitutes a gene function, then this can lead to an increase in the gene expression and thus also to a change in the activity of a protein coded by the gene concerned. Here, the sequences inserted into the genome (in particular transposons or T-DNA) are distinguished by the fact that they contain sequences, which lead to an activation of regulatory sequences of a Class 3 branching enzyme gene ("activation tagging").

[0087] Plant cells and plants according to the invention can be produced by means of the so-called "activation tagging" method (see, for example, Walden et al., Plant J. (1991), 281-288; Walden et al., Plant Mol. Biol. 26 (1994), 1521-1528). These methods are based on activating endogenous promoters by means of "enhancer" sequences, such as the enhancer of the 35S RNA promoter of the cauliflower mosaic virus, or the octopine synthase enhancer.

[0088] In conjunction with the present invention, the term "T-DNA activation tagging" is to be understood to mean a T-DNA fragment, which contains "enhancer" sequences and which leads to an increase in the activity of at least one Class 3 branching enzyme by integration into the genome of a plant cell.

[0089] In conjunction with the present invention, the term "transposon activation tagging" is to be understood to mean a transposon, which contains "enhancer" sequences and which leads to an increase in the activity of at least one Class 3 branching enzyme by integration into the genome of a plant cell.

[0090] In a preferred embodiment, the DNA molecules according to the invention, which code a Class 3 branching enzyme, are linked with regulatory sequences, which guarantee transcription in vegetable cells and lead to an increase in Class 3 branching enzyme activity in the cell. In this case, the nucleic acid molecules according to the invention are present in "sense" orientation to the regulatory sequences.

[0091] For expressing nucleic acid molecules according to the invention, which code Class 3 branching enzymes, these are preferably linked with regulatory DNA sequences, which guarantee transcription in vegetable cells. In particular, these include promoters. In general, any promoter that is active in vegetable cells is eligible for expression. At the same time, the promoter can be chosen so that expression takes place constitutively or only in a certain tissue, at a certain stage of the plant development or at a time determined by external influences. The promoter can be homologous or heterologous both with respect to the plant and with respect to the nucleic acid molecule.

[0092] Suitable promoters are, for example, the promoter of the 35S RNA of the cauliflower mosaic virus and the ubiquitin promoter from maize for constitutive expression, the patatin promoter B33 (Rocha-Sosa et al., EMBO J. 8 (1989), 23-29) for tuber-specific expression in potatoes or a promoter, which only ensures expression in photosynthetically active tissues, e.g. the ST-LS1 promoter (Stockhaus et al., Proc. Natl. Acad. Sci. USA 84 (1987), 7943-7947;

Stockhaus et al., EMBO J. 8 (1989), 2445-2451) or, for endosperm-specific expression of the HMG promoter from wheat, the USP promoter, the phaseolin promoter, promoters of zein genes from maize (Pedersen et al., Cell 29 (1982), 1015-1026; Quatroccio et al., Plant Mol. Biol. 15 (1990), 81-93), glutelin promoter (Leisy et al., Plant Mol. Biol. 14 (1990), 41-50; Zheng et al., Plant J. 4 (1993), 357-366; Yoshihara et al., FEBS Lett. 383 (1996), 213-218) or shrunken-1 promoter (Werr et al., EMBO J. 4 (1985), 1373-1380). However, promoters can also be used, which are only activated at a time determined by external influences (see for example WO 9307279). Promoters of heat-shock proteins, which allow simple induction, can be of particular interest here. Furthermore, seed-specific promoters can be used, such as the USP promoter from *Vicia faba*, which guarantees seed-specific expression in *Vicia faba* and other plants (Fiedler et al., Plant Mol. Biol. 22 (1993), 669-679; Bäumlein et al., Mol. Gen. Genet. 225 (1991), 459-467).

[0093] Furthermore, a termination sequence (polyadenylation signal) can be present, which is used for adding a poly-A tail to the transcript. A function in the stabilisation of the transcripts is ascribed to the poly-A tail. Elements of this type are described in the literature (cf. Gielen et al., EMBO J. 8 (1989), 23-29) and can be exchanged at will.

[0094] Furthermore, plant cells according to the invention and plants according to the invention can be manufactured by means of so-called "in situ activation". In this case, the introduced genetic modification effects a change in the regulatory sequences of endogenous Class 3 branching enzyme genes, which leads to an increased expression of Class 3 branching enzyme genes. Preferably, the activation of a Class 3 branching enzyme gene takes place by "in vivo" mutagenesis of a promoter or of "enhancer" sequences of an endogenous Class 3 branching enzyme gene. In doing so, a promoter or an "enhancer" sequence, for example, can be changed in such a way that the mutation produced leads to an increased expression of a Class 3 branching enzyme gene in plant cells according to the invention or plants according to the invention in comparison with the expression of a Class 3 branching enzyme gene in wild type plant cells or wild type plants. The mutation in a promoter or an "enhancer" sequence can also lead to Class 3 branching enzyme genes in plant cells according to the invention or plants according to the invention being expressed at a time at which they would not be expressed in wild type plant cells or wild type plants.

[0095] In so-called "in vivo mutagenesis", a hybrid RNA-DNA oligonucleotide ("Chimeroplast") is introduced into plant cells (Kipp, P.B. et al., Poster Session at the 5th International Congress of Plant Molecular Biology, 21st-27th September 1997, Singapore; R. A. Dixon and C.J. Arntzen, meeting report on "Metabolic Engineering in Transgenic Plants", Keystone Symposia, Copper Mountain, CO, USA, TIBTECH 15, (1997), 441-447; international patent application WO 9515972; Kren et al., Hepatology 25, (1997), 1462-1468; Cole-Strauss et al., Science 273, (1996), 1386-1389; Beetham et al., 1999, PNAS 96, 8774-8778).

[0096] A part of the DNA components of the RNA-DNA oligonucleotide is homologous to a nucleic acid sequence of an endogenous Class 3 branching enzyme gene, but, in comparison with the nucleic acid sequence of a Class 3 branching enzyme gene, it has a mutation or contains a heterologous region, which is surrounded by the homologous regions.

[0097] By base pairing of the homologous regions of the RNA-DNA oligonucleotide and the endogenous nucleic acid molecule followed by homologous recombination, the mutation or heterologous region contained in the DNA components of the RNA-DNA oligonucleotide can be transferred into the genome of a plant cell. This leads to an increase in the activity of one or more Class 3 branching enzymes.

[0098] All these methods are based on the introduction of a foreign nucleic acid molecule into the genome of a plant cell or plant and are therefore basically suitable for the manufacture of plant cells according to the invention and plants according to the invention.

[0099] Surprisingly, it has been found that plant cells according to the invention and plants according to the invention synthesise a modified starch in comparison with starch of corresponding wild type plant cells or wild type plants that have not been genetically modified.

[00100] The plant cells according to the invention and plants according to the invention synthesise a modified starch, which in its physical-chemical characteristics, in particular the amylose content or the amylose/amylopectin ratio, the degree of branching, the average chain

length, the side chain distribution, the viscosity behaviour, the gelling strength, the starch grain size and/or the starch grain morphology, is changed in comparison with the synthesised starch in wild type plant cells or wild type plants, so that this is better suited for special applications.

[00101] The present invention therefore also includes plant cells according to the invention and plants according to the invention, which synthesise a modified starch.

[00102] In conjunction with the present invention, the term "modified starch" means that the starch has changed physical-chemical characteristics compared with non-modified starch obtainable from corresponding wild type plant cells or wild type plants.

[00103] In a preferred embodiment of the present invention, the modified starch is native starch.

[00104] In conjunction with the present invention, the term "native starch" means that the starch is isolated from plants according to the invention, harvestable plant plants according to the invention or propagation material of plants according to the invention by methods known to the person skilled in the art.

[00105] Furthermore, genetically modified plants, which contain the plant cells according to the invention, are also the subject matter of the invention. Plants of this type can be produced from plant cells according to the invention by regeneration.

[00106] In principle, the plants according to the invention can be plants of any plant species, i.e. both monocotyledonous and dicotyledonous plants. Preferably they are useful plants, i.e. plants, which are cultivated by people for the purposes of food or for technical, in particular industrial purposes.

[00107] In a further preferred embodiment, the plant according to the invention is a starch-storing plant.

[00108] In a further preferred embodiment, the present invention relates to starch-storing

plants according to the invention of the genus *Solanum*, in particular *Solanum tuberosum*.

[00109] The term "starch-storing plants" includes all plants with starch-storing plant parts such as, for example, maize, rice, wheat, rye, oat, barley, cassava, potato, sago, mung bean, pea or sorghum. Preferred starch-storing plant parts are, for example, tubers, storage roots and grains containing an endosperm; tubers are particularly preferred; tubers of potato plants are especially preferred.

[00110] In conjunction with the present invention, the term "potato plant" or "potato" means plant species of the genus *Solanum*, in particular tuber-producing species of the genus *Solanum* and especially *Solanum tuberosum*.

[00111] The present invention also relates to propagation material of plants according to the invention containing a plant cell according to the invention.

[00112] Here, the term "propagation material" includes those constituents of the plant that are suitable for producing offspring by vegetative or sexual means. Cuttings, callus cultures, rhizomes or tubers, for example, are suitable for vegetative propagation. Other propagation material includes, for example, fruits, seeds, seedlings, protoplasts, cell cultures, etc. Preferably, the propagation material is seeds and particularly preferably tubers.

[00113] In a further embodiment, the present invention relates to harvestable plant parts of plants according to the invention such as fruits, storage roots, roots, blooms, buds, shoots or stems, preferably seeds or tubers, wherein these harvestable parts contain plant cells according to the invention.

[00114] Furthermore, the present invention also relates to a method for the manufacture of a genetically modified plant according to the invention, wherein

- a) a plant cell is genetically modified, whereby the genetic modification leads to an increase in the activity of a Class 3 vegetable branching enzyme in comparison with corresponding wild type plant cells that have not been genetically modified;

- b) a plant is regenerated from plant cells from Step a); and
- c) if necessary, further plants are produced with the help of the plants according to Step b).

[00115] The genetic modification introduced into the plant cell according to Step a) can basically be any type of modification, which leads to the reduction [sic?] of the activity of a Class 3 branching enzyme. The regeneration of the plants according to Step (b) can be carried out using methods known to the person skilled in the art (e.g. described in "Plant Cell Culture Protocols", 1999, ed. by R.D. Hall, Humana Press, ISBN 0-89603-549-2).

[00116] The production of further plants according to Step (c) of the method according to the invention can be carried out, for example, by vegetative propagation (for example using cuttings, tubers or by means of callus culture and regeneration of whole plants) or by sexual propagation. Here, sexual propagation preferably takes place under controlled conditions, i.e. selected plants with particular characteristics are crossed and propagated with one another.

[00117] In a preferred embodiment of the method according to the invention, the genetic modification consists in the introduction of a foreign nucleic acid molecule into the genome of the plant cell, wherein the presence or the expression of said foreign nucleic acid molecule leads to an increased activity of a Class 3 branching enzyme in the cell.

[00118] In a further preferred embodiment, the method according to the invention is used for producing potato plants according to the invention.

[00119] In a further preferred embodiment of the method according to the invention, the foreign nucleic acid molecule is chosen from the group consisting of

- a) Nucleic acid molecules, which code a protein with the amino acid sequence given under Seq ID NO 4;
- b) Nucleic acid molecules, which code a protein, the amino acid sequence of which has an identity of at least 50% with the amino acid sequence given under SEQ ID NO: 4;
- c) Nucleic acid molecules, which include the nucleotide sequence shown under Seq ID

NO 3 or a complimentary sequence;

d) Nucleic acid molecules, the nucleic acid sequence of which has an identity of at least 50% with the nucleic acid sequences described under a) or c);

e) Nucleic acid molecules, which hybridise with at least one strand of the nucleic acid molecules described under a) or c) under stringent conditions;

f) Nucleic acid molecules, the nucleotide sequence of which deviates from the sequence of the nucleic acid molecules identified under a), b), c), d), e) or f) due to the degeneration of the genetic code; and

g) Nucleic acid molecules, which represent fragments, allelic variants and/or derivatives of the nucleic acid molecules identified under a), b), c), d), e) or f).

[00120] In a further preferred embodiment of the method according to the invention, the foreign nucleic acid molecule is chosen from the group consisting of

a) T-DNA molecules, which lead to an increase in the expression of a Class 3 branching enzyme gene due to integration in the vegetable genome (T-DNA activation tagging);

b) DNA molecules, which contain transposons, which lead to an increase in the expression of a Class 3 branching enzyme gene due to integration in the vegetable genome (transposon activation tagging);

c) DNA molecules, which code a Class 3 branching enzyme and which are linked with regulatory sequences, which guarantee transcription in vegetable cells and lead to an increase in Class 3 branching enzyme activity in the cell;

d) Nucleic acid molecules introduced by means of in vivo mutagenesis, which lead to a mutation or an insertion of a heterologous sequence in at least one endogenous gene coding a Class 3 branching enzyme, wherein the mutation or insertion effects an increase in the expression of a gene coding a Class 3 branching enzyme.

[00121] The present invention also relates to the plants obtained by the method according to the invention.

[00122] In a further embodiment of the method according to the invention, the plants according to the invention synthesise a modified starch in comparison with corresponding wild

type plants that have not been genetically modified.

[00123] Surprisingly, it has been found that plant cells and plants, which have an increased activity of a Class 3 branching enzyme, synthesise a modified starch.

[00124] The present invention also relates to the plants obtained by the method according to the invention.

[00125] The present invention also relates to modified starches obtainable from plant cells according to the invention or plants according to the invention, from propagation material according to the invention or from harvestable plant parts according to the invention.

[00126] In a particularly preferred embodiment, the present invention relates to modified potato starch.

[00127] Furthermore the present invention relates to a method for the manufacture of a modified starch including the step of extracting the starch from a plant cell according to the invention or from a plant according to the invention, from propagation material according to the invention of such a plant and/or from harvestable plant parts according to the invention of such a plant, preferably from starch-storing parts according to the invention of a plant. Preferably, such a method also includes the step of harvesting the cultivated plants or plant parts and/or the propagation material of these plants before the extraction of the starch and, further, particularly preferably the step of cultivating plants according to the invention before harvesting.

[00128] Methods for extracting starches from plants or from starch-storing parts of plants are known to the person skilled in the art. Furthermore, methods for extracting starch from different starch-storing plants are described, e.g. in Starch: Chemistry and Technology (Publisher: Whistler, BeMiller and Paschall (1994), 2nd Edition, Academic Press Inc. London Ltd; ISBN 0-12-746270-8; see e.g. Chapter XII, Page 412-468: Maize and Sorghum Starches: Manufacture; by Watson; Chapter XIII, Page 469-479: Tapioca, Arrowroot and Sago Starches: Manufacture; by Corbishley and Miller; Chapter XIV, Page 479-490: Potato starch: Manufacture and Uses; by Mitch; Chapter XV, Page 491 to 506: Wheat starch: Manufacture, Modification and Uses; by

Knight and Oson; and Chapter XVI, Page 507 to 528: Rice starch: Manufacture and Uses; by Rohmer and Klem; Maize starch: Eckhoff et al., Cereal Chem. 73 (1996), 54-57, the extraction of maize starch on an industrial scale is generally achieved by so-called "wet milling".). Devices, which are in common use in methods for extracting starch from plant material are separators, decanters, hydrocyclones, spray dryers and fluid bed dryers.

[00129] In conjunction with the present invention, the term "starch-storing parts" is to be understood to mean such parts of a plant in which, in contrast to transitory leaf starch, starch is stored as a deposit for surviving for longer periods. Preferred starch-storing parts are tubers, storage roots, seeds or endosperm; particularly preferred are potato tubers or the endosperm of maize, wheat or rice plants.

[00130] Modified starch obtainable by a method according to the invention for manufacturing modified starch is also the subject matter of the present invention.

[00131] Furthermore, the use of plant cells according to the invention or plants according to the invention for manufacturing a modified starch are the subject matter of the present invention.

[00132] The person skilled in the art knows that the characteristics of starch can be changed by thermal, chemical, enzymatic or mechanical derivation, for example. Derived starches are particularly suitable for different applications in the foodstuffs and/or non-foodstuffs sector. The starches according to the invention are better suited as a starting substance for the manufacture of derived starches than conventional starches.

[00133] The present invention therefore also relates to the manufacture of a derived starch, wherein modified starch according to the invention is derived retrospectively.

[00134] In conjunction with the present invention, the term "derived starch" is to be understood to mean a modified starch according to the invention, the characteristics of which have been changed after isolation from vegetable cells with the help of chemical, enzymatic, thermal or mechanical methods. In a preferred embodiment of the present invention, the derived

starch according to the invention is starch that has been heat-treated and/or acid-treated. In a further preferred embodiment, the derived starches are starch ethers, in particular starch alkyl ethers, O-allyl ethers, hydroxylalkyl ethers, O-carboxymethyl ethers, nitrogen-containing starch ethers, phosphate-containing starch ethers or sulphur-containing starch ethers. In a further preferred embodiment, the derived starches are cross-linked starches. In a further preferred embodiment, the derived starches are starch graft polymers. In a further preferred embodiment, the derived starches are oxidised starches. In a further preferred embodiment, the derived starches are starch esters, in particular starch esters, which have been introduced into the starch using organic acids. Particularly preferably these are phosphate, nitrate, sulphate, xanthate, acetate or citrate starches.

[00135] The derived starches according to the invention are suitable for different applications in the foodstuffs and/or non-foodstuffs sector. Methods for manufacturing derived starches according to the invention are known to the person skilled in the art and are adequately described in the general literature. An overview on the manufacture of derived starches can be found, for example, in Orthoefer (in Corn, Chemistry and Technology, 1987, eds. Watson und Ramstad, Chapter 16, 479-499).

[00136] Derived starch obtainable by the method according to the invention for manufacturing a derived starch is also the subject matter of the present invention.

[00137] Furthermore, the use of modified starches according to the invention for manufacturing derived starch is the subject matter of the present invention.

Description of sequences

[00138] SEQ ID NO 1: Nucleic acid sequence containing the coding region of the 3'-area of a Class 3 branching enzyme from *Solanum tuberosum* (cv Désirée). This sequence is inserted in plasmid AN 46-196.

[00139] SEQ ID NO 2: Nucleic acid sequence containing the coding region of the 5'-area of a

Class 3 branching enzyme from *Solanum tuberosum* (cv Désirée). This sequence is inserted in plasmid AN 47-196.

[00140] SEQ ID NO 3: Nucleic acid sequence containing the full coding region of a Class 3 branching enzyme from *Solanum tuberosum* (cv Désirée). This sequence is inserted in plasmid AN 49 and was deposited with the Deutsche Sammlung von Mikroorganismen und Zellkulturen GmbH, Mascheroder Weg 1b, 38124 Braunschweig, Germany, in accordance with the Budapest Treaty on 15th September 2003 under the number DSM 15926.

[00141] SEQ ID NO 4: Amino acid sequence coding a Class 3 branching enzyme from *Solanum tuberosum* (cv Désirée). This sequence can be derived from the nucleic acid sequence inserted in plasmid AN 49 or from the nucleic acid sequence described under SEQ ID NO 3.

[00142] SEQ ID NO 5: Nucleic acid sequence containing the full coding region of a Class 3 branching enzyme from *Solanum tuberosum* (cv Désirée). This sequence has been obtained by combining the nucleic acid sequences described under SEQ ID NO 1 and SEQ ID NO 2. This nucleic acid sequence constitutes an allelic variant of the nucleic acid sequence described under SEQ ID NO 3 coding a Class 3 branching enzyme.

[00143] SEQ ID NO 6: Amino acid sequence coding a Class 3 branching enzyme from *Solanum tuberosum* (cv Désirée). This sequence can be derived from the nucleic acid sequence described under SEQ ID NO 5 and constitutes an allelic variant of the amino acid sequence described under SEQ ID NO 4 coding a Class 3 branching enzyme.

Description of the figures

[00144] Fig. 1 shows the relative amount of mRNA in seeds of genetically modified rice plants (GOAS0453), expressing a potato branching enzyme Class 3. Also shown is the example of a genetically non modified wild type plant (wt).

General methods

[00145] The following methods were used in the examples:

1. Demonstration of the activity of a Class 3 branching enzyme

[00146] The activity of a Class 3 branching enzyme was demonstrated with the help of non-denaturing gel electrophoresis as follows:

[00147] To isolate proteins from plants, the test material was ground with a pestle in liquid nitrogen, absorbed into an extraction buffer (50 mM Na citrate, pH 6.5; 1 mM EDTA, 4 mM DTT) and, after centrifugation (10 min, 14.000 g, 4 °C), was used directly for measurement of the protein content according to Bradford. Subsequently, 5 µg to 20 µg total protein extract was mixed with 4X loading buffer (20% glycerol, 125 mM Tris HCl, pH 6.8) and loaded onto a BE activity gel. The BE activity gel was made up as follows: 2.5 ml 30% acrylamide:0.8% bisacrylamide, 0.1 ml running buffer, 7.4 ml H₂O, 10% ammonium persulphate solution and 5 µl N,N,N',N'- tetramethylethylenediamine (TEMED). The running buffer (RB) was made up as follows: RB = 30.2 g Tris base, pH 8.0, 144 g glycine on 1 L H₂O. On completion of the gel run, each of the gels was incubated overnight at 37 °C in 25 ml "phosphorylase buffer" (25 ml 1M Na citrate pH 7.0, 0.47 g glucose-1-phosphate, 12.5 mg AMP, 2.5 mg phosphorylase a/b from "rabbit"). The gels were coloured with Lugol's solution.

2. Transformation of *Oryza sativa* (cv. M202)

[00148] Rice plants were transformed in accordance with the methods described by Hiei et al. (1994, Plant Journal 6(2), 271-282).

3. Starch analysis

a) Determination of the amylose content and of the amylose/amylopectin ratio

[00149] Rice flour was obtained from polished rice by milling the grains in a Cyclotec labmill to particle size smaller than 0,5 mm.

[00150] Amylose content was determined by the method of Juliano.(1971)(Cereal Science Today, 16, p334-340) with slight modifications. 50mg of rice flour are weighed in a 100ml

Erlenmeyer flask and wetted with 1 ml of 95% ethanol to avoid lumping. After addition of 9 ml of 1 M NaOH the sample is heated to 100°C for 20 min, cooled to room temperature and filled up to 100 ml with distilled water.

[00151] An aliquot of 100 µl is mixed with 10µl 1M acetic acid, 20µl Lugol solution (0,2% I₂ and 2% KI) and 970 µl water. After 10 minutes the OD at 620 nm is determined. The amylose content is calculated from a standard curve generated from samples with defined amount of potato amylose.

b) Determination of the phosphate content

[00152] In starch, the positions C2, C3 and C6 of the glucose units can be phosphorylated.

Determination of C6-P content of rice starch is performed either on single mature grains hydrolysed in 200 µl of 0,7 M HCl or on 50 mg rice flour hydrolysed in 500 µl 0,7 M HCl.

After 4 h hydrolysis at 95°C under continuous shaking, samples are centrifuged for 10 minutes at 15500xg and the supernatants are applied to a spin module containing 0,2 µm PTFE-filter membran for complete clarification of the hydrolyzate (5 min 1000xg). 20 µl of the supernatants are mixed with 180 µl of imidazole buffer (300 mM imidazole, pH 7.2; 7,5 mM MgCl₂, 1 mM EDTA and 0.4 mM NADP). The measurement was carried out in a photometer at 340 nm. After the base absorption had been established, the enzyme reaction was started by addition of 0,4 units glucose-6-phosphate dehydrogenase (from *Leuconostoc mesenteroides*, Boehringer Mannheim). The change in absorption is directly proportional to the concentration of the G-6-P content of the starch.

[00153] The total phosphate content was determined by the method of Ames (Methods in Enzymology VIII, (1966), 115-118).

[00154] Approximately 50 mg of starch are treated with 30 µl of ethanolic magnesium nitrate solution and ashed for 3 hours at 500°C in a muffle oven. The residue is treated with 300 µl of 0.5 M hydrochloric acid and incubated for 30 minutes at 60°C. One aliquot is subsequently made up to 300 µl 0.5 M hydrochloric acid and this is added to a mixture of 100 µl of 10% ascorbic acid and 600 µl of 0.42% ammonium molybdate in 2 M sulphuric acid and incubated for 20 minutes at

45°C.

[00155] This is followed by a photometric determination at 820 nm with a phosphate calibration series as standard.

c) Determination of the viscosity characteristics by means of a Rapid Visco Analyser (RVA)
[00156] 3 g of rice flour (DM) are taken up in 25 ml of H₂O (VE-type water, conductivity of at least 15 mega ohm) and used for the analysis in a Rapid Visco Analyser Super3 (Newport Scientific Pty Ltd., Investmet Support Group, Warriewood NSW 2102, Australia). The apparatus is operated following the manufacturer's instructions. The viscosity values are indicated in Centipoise (cP) in accordance with the manufacturer's operating manual, which is incorporated into the description herewith by reference. To determine the viscosity of the aqueous starch solution, the starch suspension is first stirred for 10 seconds at 960 rpm and subsequently heated at 50°C at a stirring speed of 160 rpm, initially for a minute (step 1). The temperature was then raised from 50°C to 95°C at a heating rate of 12°C per minute (step 2). The temperature is held for 2.5 minutes at 95°C (step 3) and then cooled from 95°C to 50°C at 12°C per minute (step 4). In the last step (step 5), the temperature of 50°C is held for 2 minutes. The viscosity is determined during the entire duration.

[00157] After the program has ended, the stirrer is removed and the beaker covered. The gelatinized starch is now available for the texture analysis after 24 hours incubation at room temperature.

[00158] The profile of the RVA analysis contains parameters which are shown for the comparison of different measurements and substances. In the context of the present invention, the following terms are to be understood as follows:

1. Maximum viscosity (RVA Max)

[00159] The maximum viscosity is understood as meaning the highest viscosity value, measured in cP, obtained in step 2 or 3 of the temperature profile.

2. Minimum viscosity (RVA Min)

[00160] The minimum viscosity is understood as meaning the lowest viscosity value, measured in cP, observed in the temperature profile after the maximum viscosity. Normally, this takes place in step 3 of the temperature profile.

3. Final viscosity (RVA Fin)

[00161] The final viscosity is understood as meaning the viscosity value, measured in cP, observed at the end of the measurement.

4. Setback (RVA Set)

[00162] What is known as the “setback” is calculated by subtracting the value of the final viscosity from that of the minimum occurring after the maximum viscosity in the curve.

5. Gelatinization temperature (RVA PT)

[00163] The gelatinization temperature is understood as meaning the point in time of the temperature profile where, for the first time, the viscosity increases drastically for a brief period.

d) Determination of the gel strength (Texture Analyser)

[00164] 3 g of rice flour (DM) are gelatinized in the RVA apparatus in 25 ml of an aqueous suspension (temperature program: see item c) “Determination of the viscosity characteristics by means of a Rapid Visco Analyser (RVA)”) and subsequently stored for 24 hours at room temperature in a sealed container. The samples are fixed under the probe (round piston with planar surface) of a Texture Analyser TA-XT2 from Stable Micro Systems (Surrey, UK) and the gel strength was determined using the following parameters:

- | | | |
|---|----------------------|---------------------|
| - | Test speed | 0.5 mm/s |
| - | Depth of penetration | 7 mm |
| - | Contact surface | 113 mm ² |
| - | Pressure | 2 g |

e) Analysis of the side-chain distribution of the amylopectin by means of ion-exchange chromatography

Definition Pfam Isoamylase N Domain

Pfam entry Isoamylase N



Figure 1: 1z0m
SUGAR BINDING PROTEIN
 THE GLYCOGEN-BINDING DOMAIN OF THE
 AMP-ACTIVATED PROTEIN KINASE BETA1
 SUBUNIT

Key:

Domain	Chain	Start Residue	End Residue
<u>Isoamylase N</u>	A	74	147
<u>Isoamylase N</u>	B	74	147
<u>Isoamylase N</u>	C	74	147

The Swissprot/PDB mapping was provided by MSD

1bf2 ☐ Display

Accession number: PF02922

Previous identifiers: isoamylase_N;

Isoamylase N-terminal domain

This domain is found in a range of enzymes that act on branched substrates - isoamylase, pullulanase and branching enzyme. This family also contains the beta subunit of 5' AMP activated kinase.

This family forms **interactions** with other Pfam families, to view them click [here](#)

Add Annotation

INTERPRO description (entry IPR004193)

O-Glycosyl hydrolases (EC 3.2.1.-) are a widespread group of enzymes that hydrolyse the glycosidic bond between two or more carbohydrates, or between a carbohydrate and a non-carbohydrate moiety. A classification system for glycosyl hydrolases, based on sequence similarity, has led to the definition of 85 different families [PUBMED:7624375](#), [PUBMED:8535779](#), [PUBMED](#). This classification is available on the CAZy (Carbohydrate-Active EnZymes) web site [PUBMED](#). Because the fold of proteins is better conserved than their sequences, some of the families can be grouped in 'clans'.


Enzymes containing this domain belong to family 13 () of the glycosyl hydrolases. This domain is found in a range of enzymes that act on branched substrates ie. isoamylase, pullulanase and branching enzyme. Isoamylase hydrolyses 1,6-alpha-D-glucosidic branch linkages in glycogen, amylopectin and dextrin; 1,4-alpha-glucan branching enzyme functions in the formation of 1,6-glucosidic linkages of glycogen; and pullulanase is a starch-debranching enzyme.

QuickGO

Function	hydrolase activity, hydrolyzing O-glycosyl compounds (GO:0004553)
Process	carbohydrate metabolism (GO:0005975)

Alignment

Domain organisation

<input checked="" type="checkbox"/> Seed (60) <input type="checkbox"/> Full (1021) Coloured alignment Format: <input type="text"/>	<input checked="" type="checkbox"/> View 33 representative architectures <input type="checkbox"/> View architectures for 1021 proteins Zoom: <input type="text"/> 0.5 pixels/aa.
Further alignment options here Help relating to Pfam alignments here	<input checked="" type="checkbox"/> Seed (60) <input type="checkbox"/> Full (1021) 
Species Distribution NEW! View alignments & domain organisation by species Tree depth: <input type="text"/> Show all levels <input type="button" value="View Species Tree"/>	The trees were generated using Quicktree To find out more about ATV phylogenetic tree-viewer click here

Database References

PDB

You can find out how to set up Rasmol [here](#)

1m7x B; 124; 207;

PFAM

PRC + PRODOM:PB013218
 PRODOM only:PB007160 PB074080 PB134203 PB150229 PB179603 PB183243

SYSTEMS

isoamylase N

PANDIT

isoamylase N

FUNSHIFT

isoamylase N

Literature References		Pfam specific information	
1.	A novel domain in AMP-activated protein kinase causes glycogen storage bodies similar to those seen in hereditary cardiac arrhythmias. Hudson ER, Pan DA, James J, Lucocq JM, Hawley SA, Green KA, Baba O, Terashima T, Hardie DG; Curr Biol 2003;13:861-866.	Author of entry	Griffiths-Jones SR
2.	AMPK beta subunit targets metabolic stress sensing to glycogen. Polekhina G, Gupta A, Michell BJ, van Denderen B, Murthy S, Fell SC, Jennings IG, Campbell DJ, Witters LA, Parker MW, Kemp BE, Stapleton D; Curr Biol 2003;13:867-871.	Type definition	Domain
3.	Mutations in the gal83 glycogen-binding domain activate the snf1/gal83 kinase pathway by a glycogen-independent mechanism. Wiatrowski HA, Van Denderen BJ, Berkeley CD, Kemp BE, Stapleton D, Carlson M; Mol Cell Biol 2004;24:352-361.	Source of seed members	Structural domain
4.	Three-dimensional structure of Pseudomonas isocitrate lyase at 2.2 Å resolution. Katsuya Y, Mezaki Y, Kuibota M, Matsuura Y; J Mol Biol 1998;281:885-897.	Average Length	25
		Average %id	12.70
		Average Coverage	CHANGE%
		HMMER build information	
		Pfam_Is [Download HMM]	Pfam_fs [Download HMM]
		Gathering cutoff	16.0 16.0
		Trusted cutoff	16.0 16.0
		Noise cutoff	15.9 15.9
		Build method of HMM	hmmbuild -F HMM_Is SEED hmmcalibrate -cpu 1 --seed 0 HMM_Is

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Annex 2

Definition of Pfam Alphaamylase Domain

Pfam entry Alpha-amylase

Accession number: PF00128

Previous identifiers: alpha-amylase;

Alpha amylase, catalytic domain

Alpha amylase is classified as family 13 of the glycosyl hydrolases. The structure is an 8 stranded alpha/beta barrel containing the active site, interrupted by a ~70 a.a. calcium-binding domain protruding between beta strand 3 and alpha helix 3, and a carboxyl-terminal Greek key beta-barrel domain.

This family forms **interactions** with other Pfam families, to view them click [here](#)

Add a mutation

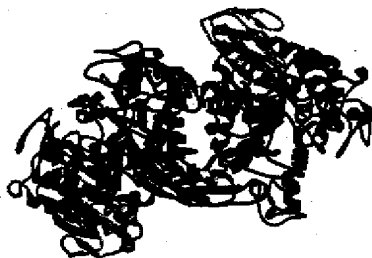


Figure 1: 1vfk
CRYSTAL STRUCTURE OF
THERMOACTINOMYCES VULGARIS R-47
ALPHA- AMYLASE 2-ACARBOSE COMPLEX

Key:

Domain	Chain	Start Residue	End Residue
<u>Alpha- amylase</u>	A	135	494
<u>Alpha- amylase N</u>	A	1	117
<u>Alpha- amylase</u>	B	135	494
<u>Alpha- amylase N</u>	B	1	117

The Swissprot/PDB mapping was provided by MSD

Tim barrel glycosyl hydrolase superfamily

This family is a member of the Tim barrel glycosyl hydrolase superfamily clan. This clan includes the following Pfam members: Glyco_hydro_92; Glyco_hydro_77; Glyco_hydro_72; Glyco_hydro_70; Glyco_hydro_59; Glyco_hydro_56; Glyco_hydro_53; Glyco_hydro_42; Glyco_hydro_39; Glyco_hydro_35; Glyco_hydro_31; Glyco_hydro_30; Glyco_hydro_3; Glyco_hydro_2_C; Glyco_hydro_26; Glyco_hydro_25; Glyco_hydro_20; Glyco_hydro_18; Glyco_hydro_17; Glyco_hydro_14; Glyco_hydro_10; Glyco_hydro_1; DUF187; Cellulase; Alpha-amylase; Melliase;

INTERPRO description (entry IPR006047)

O-Glycosyl hydrolases (EC 3.2.1.-) are a widespread group of enzymes that hydrolyse the glycosidic bond between two or more carbohydrates, or between a carbohydrate and a non-carbohydrate moiety. A classification system for glycosyl hydrolases, based on sequence similarity, has led to the definition of 85 different families [PUBMED:7624375](#), [PUBMED:8535779](#), [PUBMED](#). This classification is available on the CAZy (Carbohydrate-Active Enzymes) web site [PUBMED](#). Because the fold of proteins is better conserved than their sequences, some of the families can be grouped in 'clans'.

Enzymes containing this domain, such as alpha-amylase, belong to family 13 () of the glycosyl hydrolases. The maltogenic alpha-amylase is an enzyme which catalyses hydrolysis of (1-4)-alpha-D-glucosidic linkages in polysaccharides so as to remove successive alpha-maltose residues from the non-reducing ends of the chains in the conversion of starch to maltose. Other enzymes include neopullulanase, which hydrolyses pullulan to panose, and cyclomaltodextrinase, which hydrolyses cyclodextrins.

This entry represents the catalytic domain found in several protein members of this family. It has a structure consisting of an 8 stranded alpha/beta barrel that contains the active site, interrupted by a ~70 amino acid calcium-binding domain protruding between beta strand 3 and alpha helix 3, and a carboxyl-terminal Greek key beta-barrel domain [PUBMED:16302977](#).

<div>1a47</div>		More information about this protein can be found at Protein of the Month: alpha-Amylase PUBMED .	
		<div>QuickGO</div>	
Function		cation binding (GO:0043169)	
		catalytic activity (GO:0003824)	
Process		carbohydrate metabolism (GO:0005975)	

Alignment	Domain organisation
<div> <input checked="" type="checkbox"/> Seed (54) <input type="checkbox"/> Full (3295) </div> <div> Format <input type="text" value="Coloured alignment"/> </div> <div> <input type="button" value="Get alignment"/> </div> <div> Further alignment options here Help relating to Pfam alignments here </div>	<div> <input checked="" type="checkbox"/> View 81 representative architectures <input type="checkbox"/> View architectures for 3295 proteins </div> <div> Zoom <input type="text" value="0.5"/> pixels/aa. <input type="button" value="View Graphics"/> </div>
<div> Species Distribution View alignments & domain organisation by species </div> <div> Tree depth: <input type="text" value="Show all levels"/> </div> <div> <input type="button" value="View Species Tree"/> </div>	<div> <input checked="" type="checkbox"/> Seed (54) <input type="checkbox"/> Full (3295) <input type="button" value="Download tree"/> </div> <div> The trees were generated using Quicktree To find out more about ATV phylogenetic tree-viewer click here </div>

Database References	
PDB You can find out how to set up Rasmol here	<div>1m7x A; 285; 338;</div>

	hmmcalibrate --cpu 1 --seed 0 HMM_ls	hmmcalibrate --cpu 1 --seed 0 HMM_fs
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Annex 3

Pfam motive of amino acid sequence as disclosed in US 10/573,999

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 Pfam family ID
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 Getting started
 Guide to domains
 Create your own domain images
 Changes from last release
 Pfam MySQL documentation
 Planned changes to Pfam
 FAQ on Pfam
 Linking to Pfam
 Using Biopython to view alignments

residues]

Trusted matches - domains scoring higher than the gathering threshold (A)

Domain	Start	End	Bits	Evalue	Alignment	Mode
Isoamylase N	125	212	6.70	0.021	Align	ls
Alpha-amylase	414	803	-76.10	0.0025	Align	ls
Alpha-amylase C	804	897	85.10	1.9e-22	Align	ls

Matches to Pfam-B

Domain	Start	End	Alignment
Pfam-B 128458	1	336	Align
Pfam-B 150229	337	382	Align
Pfam-B 65794	412	447	Align
Pfam-B 186	503	640	Align

Potential matches - Domains with Evalues above the cutoff

Domain	Start	End	Bits	Evalue	Alignment	Mode
Isoamylase N	338	364	0.60	7.1	Align	fs
DUF1247	576	589	2.40	0.9	Align	fs

Alignments of Pfam-A domains to HMMs

JaView Java alignment viewer

Format for fetching alignments to seed

Alignment of Isoamylase_N vs UNKNOWN-QUERY/125-212

```
*->PLGAhydpddtdvGevggvNFrVWAPnAerVsLvldfnnggkdwde
+G h+ ++ v F +WAP+A+ ++L++dfn+ w ++
UNKNOWN-QU 125 LMGHNRNIQH-----RVDFLEWAPGARYCALIGDFNG----WSTT 160

ehpmkrs..etnrdgGvWelfpGdnGpdlkhgsGgvrYkYritgpdape
+ ++++ + ++d G+W + l++ l +g + + ++
UNKNOWN-QU 161 GNCAREGHfG-HDDYGYWFIILED----KLREGEEPDKLYFQQYNYA--- 202

eChrfneiklklDPYA<-*
e ++k D +
UNKNOWN-QU 203 -----EDYDKGDTGI 212
```

Alignment of Alpha-amylase vs UNKNOWN-QUERY/414-803

```
*->qipydrFewgDpsndpsssyGsaagcrdrePtggieIrkyfGGDLqG
+ + +F+
UNKNOWN-QU 414 EPKVSSFN-----DF 423

iIdklYlkdLgvtaiWlsPifenipntaspqkdstsybgYdttdYkkin
i + l+ k++G++a ++ ++e + + gY +t+++++
UNKNOWN-QU 424 ISKVLPHVKEAGYNATQIIIGVVE-----HKD---YFTVGYRVTFNFIYAV- 463

QGvdpryGtKadfkSLidaaharGIKvildVpNhtsdehavedvtfques
+tryGt +dfk+L+d+ah +G v l +v H+ ++ a e+v +
UNKNOWN-QU 464 ---SSRYGTPDDEKRLVDEAHGLGLLVELEIV--HS-YAAADEMV-----G 503

nkskdnpedygyyiewfpgklspgpnysptnwgshkfdlyfdgsnwsd
+ d d+y+ ++gk+ ++++
UNKNOWN-QU 504 LSLFDGA---NDCYF--HTGKR-----GHHK-----FWGTRMEFY 533

gdengdeyyhlflvgLpDLnteNpe.....Vr
```

UNKNOWN-QU 534 GDPDL-----HFLSLNLNWVE-EYhvdgfhfslssmlythngfasFT 577
 gd ++ *fl + *** e *** ++ + ++ ++ **** ++
 neikdlaklWldkGgelGvDGFRiDaakHiskdnggflkeftqelkayk
 + ** **** ++ a + + e ++l+
 UNKNOWN-QU 578 GDMDEYCNQYVDKE-----ALLYLI-----LANEVLHALH--- 607
 esgpevftvGEvwsgdgelargdaytgygeltmlfdEplfgilqnafrp
 p+v t++ v + + ++ +++++ F++f+ l ++
 UNKNOWN-QU 608 ---PNVITIA-VDA---T---LYPLCLDPTSQGLGFDYFANLSASE-- 644
 nkf...qgnpqdqaStmkdlknmisgwqsaypnavekavtFvdNHDtpRg
 ++ n+ d +m+++++ + ++ n ++k+ + +NH ++ +
 UNKNOWN-QU 645 -MwlaLLENTPDHEWCMKIVSTL---VGDQRQN-TDKMLLYAENHNQS-I 688
 hgl.dflsrtggdrsk.....
 g++++f+ + g++ +k++ +++++ ++ + ++ + +++ +++ +
 UNKNOWN-QU 689 SGRSFAEILIGNSLGKssisqesllrgcslhkmirlitstiggghaylnf 738
A.kyrvkkklAyafiltspyGtPvIYy
 +++ +++++ + +++++ + +tr++++l + ++ +
 UNKNOWN-QU 739 mgnefghpkrvefpmssnnfslANRRWDLEDVVHYQLFS-----FD 782
 GdElgmtggkgnidisPnmmdnregnpwsdehrdtelyqqiksldafR<-
 d+++ + ++ + +++++
 UNKNOWN-QU 783 KDMMDLDKNG-----RILSRGLANIH 803
 *

UNKNOWN-QU - -

►Alignment of Alpha-amylase C vs UNKNOWN-QUERY/804-897

*->WidadDngnsviAFeRrgdkgnkgdddlvvfnftpvdsredyvt
 + ++ vi++R g + l+vfnf+pv+s+e y +
 UNKNOWN-QU 804 H---VNDTITMVISYLR-----GPN---LFVFNFPVNSYERY-II 836

UNKNOWN-QU 837 GVEEAG---EYQVTL--NTDENKYGGRGILGHDQNTQRT---ISR----R 874

gLPqGggtYrdvlglnsDaeeyGGsg.lgnsgotGrkptvvtVteeep
g+++aG +Y++ 1 nD+ +yGG g lg++ t r+ +++
wvdGrkpySwgltltlPplsalvLhlkak<--*
dG +++ 1++ 1P++sa v++l + 897

UNKNOWN-QU

►Alignment of Isoamylase N vs UNKNOWN-QUERY/338-364

->pdllkhsGgvrykYritgpdapeeGhrfneiklklDPYA<--
p+l+hgs + + +p+ G + ++++++A 364
PALPHGS---KHRVYFNTPN---G-----P-LERVEAWA 364

UNKNOWN-QU 338

►Alignment of DUF124Z vs UNKNOWN-QUERY/576-589

->FrknrkthvDeYVe<--
F+++++++ YV+
FTGDMDEYCNQYVD 589

UNKNOWN-QU 576

Alignments of Pfam-B domains to best-matching to Pfam-B sequence

Hypertext linked to sw iss pfam

Format for fetching alignments to Pfam-B families:

►Query Query/1-336 matching Pfam-B_128458

temp 1 MSLSDSIRISSPLSDSRLSFLSQTGSRTSRQLKFVRSRRARVSRRCSCSA 50
Query 1 MSLSDSIRISSPLSDSRLSFLSQTGSRTSRQLKFVRSRRARVSRRCSCSA 50

temp 51 TEQPPQRRKQRPKEYKQSEEEKGIDPVGFLSKYGITHKAFQFLRERYK 100
 TEQPPQRRKQRPKEYKQSEEEKGIDPVGFLSKYGITHKAFQFLRERYK
 Query 51 TEQPPQRRKQRPKEYKQSEEEKGIDPVGFLSKYGITHKAFQFLRERYK 100

temp 101 SLKDLKDEILTRHFSLEKEMSTGYELMGHMRNIQHRVDFLEWAPGARYCAL 150
 SLKDLKDEILTRHFSLEKEMSTGYELMGHMRNIQHRVDFLEWAPGARYCAL
 Query 101 SLKDLKDEILTRHFSLEKEMSTGYELMGHMRNIQHRVDFLEWAPGARYCAL 150

temp 151 IGDENGWSTTGNCCAREGHEGHDHDDYGYWFIILEDKLRGEEDPKLYFQQYN 200
 IGDENGWSTTGNCCAREGHEGHDHDDYGYWFIILEDKLRGEEDPKLYFQQYN
 Query 151 IGDENGWSTTGNCCAREGHEGHDHDDYGYWFIILEDKLRGEEDPKLYFQQYN 200

temp 201 YAEDYDKGDTGITVEEIEFKKANDEYWEPEGEDRFIKSRYEVAAKLYEEMFG 250
 YAEDYDKGDTGITVEEIEFKKANDEYWEPEGEDRFIKSRYEVAAKLYEEMFG
 Query 201 YAEDYDKGDTGITVEEIEFKKANDEYWEPEGEDRFIKSRYEVAAKLYEEMFG 250

temp 251 PNGPQTEEELEAMPDAAATRYKTWKEQKKDPASNLP SYDVVDSGKEYDIY 300
 PNGPQTEEELEAMPDAAATRYKTWKEQKKDPASNLP SYDVVDSGKEYDIY
 Query 251 PNGPQTEEELEAMPDAAATRYKTWKEQKKDPASNLP SYDVVDSGKEYDIY 300

temp 301 NIIGDPESFKFRMKOPPIAYWLETKKGRKGWLQKY 336
 NIIGDPESFKFRMKOPPIAYWLETKKGRKGWLQKY
 Query 301 NIIGDPESFKFRMKOPPIAYWLETKKGRKGWLQKY 336



►Query Query/337-382 matching Pfam-B 150229

temp 337 MPALPHGSKHRVYFNTPNGPLERVPAWANFVIPDADGMALAVHWE 382
 MPALPHGSKHRVYFNTPNGPLERVPAWANFVIPDADGMALAVHWE
 Query 337 MPALPHGSKHRVYFNTPNGPLERVPAWANFVIPDADGMALAVHWE 382



►Query Query/412-447 matching Pfam-B 65794

temp 412 GQEPKVSSFNDFISKVLPHVKEAGYNATQIIIGVVEH 447
 GQEPKVSSFNDFISKVLPHVKEAGYNATQIIIGVVEH
 Query 412 GQEPKVSSFNDFISKVLPHVKEAGYNATQIIIGVVEH 447

►Query Query/503-640 matching Pfam-B 186

temp 503 GLSLEDGANDCYFHTGKRGHKFWGTRMFKYGDVVLHFLLSNLNWWVEE 552
GLSLEDGANDCYFHTGKRGHKFWGTRMFKYGDVVLHFLLSNLNWWVEE
Query 503 GLSLEDGANDCYFHTGKRGHKFWGTRMFKYGDVVLHFLLSNLNWWVEE 552
temp 553 YHVDGFHFHSLSSMLYTHNGFASFTGDMDEYCNQYVDKEALLYLILANEV 602
YHVDGFHFHSLSSMLYTHNGFASFTGDMDEYCNQYVDKEALLYLILANEV
Query 553 YHVDGFHFHSLSSMLYTHNGFASFTGDMDEYCNQYVDKEALLYLILANEV 602
temp 603 LHALHPNVITIAVDATLYPGLCDPTSQGGGLGFDYFANL 640
LHALHPNVITIAVDATLYPGLCDPTSQGGGLGFDYFANL
Query 603 LHALHPNVITIAVDATLYPGLCDPTSQGGGLGFDYFANL 640

Aligned family

Comments or questions on the site? Send a mail to pfam-help@sanger.ac.uk

Annex 4

NCBI Nucleotide [Sign In] [R]

PubMed Nucleotide Protein Genome Structure PMC Taxonomy OMIM

Search for

Display Show Send to Hide: ☐ sequence ☐ all but gene, CDS and mR

Range: from to ☐ Reverse complemented strand Features:

☐ 1: [A22363](#). Reports Plasmid DNA from ...[gi:904243]

[Links](#)

Features **Sequence**

LOCUS A22363 2909 bp DNA linear PAT 04-MAY-1995
DEFINITION Plasmid DNA from patent WO9214827.
ACCESSION A22363
VERSION A22363.1 GI:904243
KEYWORDS .
SOURCE synthetic construct
ORGANISM synthetic construct
other sequences; artificial sequences.
REFERENCE 1 (bases 1 to 2909)
AUTHORS .
TITLE PLASMIDS CONTAINING DNA-SEQUENCES THAT CAUSE CHANGES IN THE CARBOHYDRATE CONCENTRATION AND THE CARBOHYDRATE COMPOSITION IN PLANTS, AS WELL AS PLANT CELLS AND PLANTS CONTAINING THESE PLASMIDS
JOURNAL Patent: WO 9214827-A 1 03-SEP-1992;
FEATURES Location/Qualifiers
source 1..2909
/organism="synthetic construct"
/mol_type="unassigned DNA"
/db_xref="taxon:32630"

ORIGIN

```
1 tcaggagcgg tcttgggata tttcttccac cccaaaatca agagttagaa aagatgaaag
61 gatgaagcac agttcagcta tttccgctgt ttgaccgat gacaattcga caatggcacc
121 cctagaggaa gatgtcaaca ctgaaaatat tggcctccta aatttggatc caactttgga
181 accttatcta gatcacttca gacacagaat gaagagatat gtggatcaga aaatgctcat
241 tgaaaaatat gagggacccc ttgaggaatt tgctcaaggt tatttaaaat ttggattcaa
301 caggggaagat ggttgcatag tctatcgtga atgggctcct gctgctcagg aagcagaagt
361 tattggcgat ttcaatggta ggaacgggtt taaccacatg atggagaagg accagtttgg
421 tgtttggagt attagaattc ctgatgttga cagtaagcca gtcattccac acaactccag
481 agttaagttt cgtttcaaac atggtaatgg agtgtgggta gatcgtatcc ctgcttggat
541 aaagtatgcc actgcagacg ccacaaagtt tgcagcacca tatgatggtg tctactggga
601 cccaccacct tcagaaaggt accacttcaa ataccctcgc cctcccaaac cccgagcccc
661 acgaatctac gaagcacatg tggcctatgag cagctctgag ccacgtgtaa attcgtatcg
721 tgagtttgca gatgatgttt tacctcggat taaggcaaat aactataata ctgtccagtt
781 gatggccata atggaacatt cttactatgg atcatttggg tatcatgtta caaacttttt
841 tgctgtgagc aatagatatg gaaacccgga ggacctaaag tatctgatag ataaagcaca
901 tagcttgggt ttacagggtc tgggtgatgt agttcacagt catgcaagca ataagtgcac
961 tgatggcctc aatggctttg atattggcca aggttctcaa gaatcctact ttcattgctg
1021 agagcgaggg taccataagt tgtgggtag caggtgttcc aactatgcca attgggaggt
1081 tcttcgtttc cttctttcca acttgagggtg gtggctagaa gagtataact ttgacggatt
1141 tcgatttgat ggaataaact ctatgctgta tgttcatcat ggaatcaata tgggatttac
1201 aggaaactat aatgagtatt tcagcgaggc tacagatgtt gatgctgtgg tctatttaat
1261 gttggccaat aatctgattc acaagatttt cccagacgca actgttattg ccgaagatgt
1321 tcttggtatg cgggcctta gccggcctgt ttctgagggg ggaattgggt ttgattaccg
1381 cctggcaatg gcaatcccag ataagtggat agattattta aagaataaga atgatgaaga
1441 ttggtccatg aaggaagtaa catcgagttt gacaaatagg agatatacag agaagtgtat
1501 agcatatgcg gagagccatg atcagtttat tgcggtgac aagaccattg catttctcct
1561 aatgaacaaa gagatgtatt ctggcatgtc ttgcttgaca gatgcttctc ctgttgttga
1621 tgcaggaatt gcgcttgaca agatgatcca tttttttcac aatggccttg ggaggagagg
1681 ggtacctcaa tttcatgggt aacgagtttg gccatcctga gtggattgac ttccctagt
```

1741 agggcaataa ttggagttat gacaaatgta gacgccagtg gaacctcgca gatagcgaac
1801 acttgagata caagtttatg aatgcatttg atagagctat gaattcgctc gatgaaaagt
1861 tctcattcct cgcacagga aaacagatag taagcagcat ggatgatgat aataaggttg
1921 ttgtgtttga acgtggtgac ctggtatttg tattcaactt ccacccaaat aacacatacg
1981 aagggataaa agttggatgt gacttgccag ggaagtacag agttgcactg gacagtgatg
2041 cttgggaatt tggaggccat ggaagagctg gtcacatgtg tgaccatttc acatcaccag
2101 aaggaatacc tggagttcca gaaacaaatt tcaatggctg tccaaattcc ttcaaagtgc
2161 tgtctcctgc gcgaacatgt gtggcttatt acagagttga tgaacgcatg tcataaactg
2221 aagattacca gacagacatt tgtagttagc tactaccaac agccaatata gaggaaagtg
2281 acgagaaact taaagattca tcatctacaa atatcagtag atcatctaca aaaaatgctt
2341 attacagagt tgatgaacgc atgtcagaag ctgaagatta ccagacagac attttagtg
2401 agctactact accaacagcc aatatcgagg agagttagca gaaacttgat gattcattat
2461 ctacaaatat cagtaacatt ggtcagactg ttgtagtctc tgttgaggag agagacaagg
2521 aacttaaaga ttcaccatct gtaagcatca ttagtgatgc tgttccagct gaatgggctg
2581 attcggatgc aaacgtctgg ggtgaggact agtcagatga ttgatcgatc cttctacgtt
2641 ggtgatctcg gtccgtgcat gatgtcttca ggggtgtagc attgactgat tgcacatag
2701 tttttttttt tttttttaag tatttctct atgcatatta ttagcatcca ataaatttac
2761 tgggtgttgt acatagaaaa agtgcatttg catgtatgtg tttctctgaa attttcccca
2821 gttttggtgc tttgcctttg gagccaagtc tctatatgta ataagaaaac taagaacaat
2881 cacatatata aaatgttagt agattacca

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Last update: Thu, 26 Jun 2008 Rev. 132340

Annex 5

Annex 5

Pfam motive of amino acid sequence deduced from the nucleotide sequence as disclosed in
EP 1103617 A2.doc



Pfam

RSS

Protein family of sequence
Keyword
Domain query
DNA sequence
Taxonomy query
Pfam family ID
Genomes
Clans
Interaction
Hyperlink directly to the Pfam site
View FTP sites
Pfam home pages
Browse Pfam
Main help page
Getting started
Guide to domains
Create your own domain images
Changes from last release
Pfam MySQL documentation
Printed changes to Pfam

residues]

Trusted matches - domains scoring higher than the gathering threshold (A)

Domain	Start	End	Bits	Evalue	Alignment	Mode
Isoamylase N	76	160	95.90	1.1e-25	Align	ls
Alpha-amylase	201	532	47.20	0.00015	Align	ls

Matches to Pfam-B

Domain	Start	End	Alignment
Pfam-B 1450	21	68	Align
Pfam-B 1269	186	210	Align
Pfam-B 65794	211	251	Align
Pfam-B 186	295	504	Align
Pfam-B 1204	505	544	Align

Potential matches - Domains with Evalues above the cutoff

Domain	Start	End	Bits	Evalue	Alignment	Mode
PRE	55	67	1.70	0.67	Align	fs

IGPS	268	288	3.60	0.73	Align	fs
------	-----	-----	------	------	-------	----

Alignments of Pfam-A domains to HMMs

Java view alignment viewer

Format for fetching alignments to seed

► Alignment of Isoamylase N vs UNKNOWN-QUERY/76-160

```
*-> pLGahydpddtvdGevggvnFrvWAPnAerVsLvldfnnggkdw dge
++G+++          e+g +++r+WAP+A+++++dfn+ ++g
UNKNOWN-QU      76  KGFENR-----EDGIVYREWAPAAQAEVIGDFNG----RNGS 110
```

```
ehpmkrsetnrdgGvWelflpgd.nG.pdlkhgsGgvrykYritgp dape
h m+ ++ +GvW++ +p d + +p +th+s r+k+r+++++
UNKNOWN-QU      111 NHMME----KQQFGVWSIRIP-DvDSkPVI PHNS---RVKFRFKHGN--- 149
```

```
eGhrfneiklklDPYA<-*
G ++++++++
UNKNOWN-QU      150 -G----VWVDRI PAWI 160
```



► Alignment of Alpha-amylase vs UNKNOWN-QUERY/201-532

```
*-> qiypdrFwgDpsndps.ssyGsaagcrdrePtqgielrkyfGGDlq
iy +s p+ +sy
UNKNOWN-QU      201 RIYEAHVG--MSSEPRVNSYR-----E 221
```

```
GlidklYLkdlGvtaiWlsPifenipntaspqkdstsyhgYdttdYkkl
d l+ +k ++ ++l+ i e + ++ +gY+++ +++++
UNKNOWN-QU      222 FADDVLPRIKANNYNTVQLMAIME-----HSY---YGSFGYHVTNFFAV 262
```

```
nQgvdpryGt kdfksLidaaharGIKvildVpNhtsdehavedvtfge
ryG+ +d+k Lid+ah++G +v++DvV H+ ++ +
UNKNOWN-QU      263 ----SNRYGNPEDLKYLIDKAHSLGLQLVLDVV--HS-HASNN----- 298
```


->sdelleeyArsIGMeVLV<-
+ e L+ L++ A+slG++vLV
UNKNOWN-QU 268 NPEDLYLIDKAHSLGLQLV 288

Alignments of Pfam-B domains to best-matching to Pfam-B sequence

Format for fetching alignments to Pfam-B families:

HyperText linked to swisspfam

►Query Query/21-68 matching Pfam-B 1450

temp 21 LEEDVNTENIGLLNLDPTLEPYLDHFRHRMKRYVDQKMLIEKYEGL 68
LEEDVNTENIGLLNLDPTLEPYLDHFRHRMKRYVDQKMLIEKYEGL
Query 21 LEEDVNTENIGLLNLDPTLEPYLDHFRHRMKRYVDQKMLIEKYEGL 68

►Query Query/186-210 matching Pfam-B 1269

temp 186 RYHFKYPRPPKPRAPRIYEAHVMS 210
RYHFKYPRPPKPRAPRIYEAHVMS
Query 186 RYHFKYPRPPKPRAPRIYEAHVMS 210

►Query Query/211-251 matching Pfam-B 65794

temp 211 SSEPRVNSYREFADDVLPRIKANNYNTVOLMAIMEHSYYS 251
SSEPRVNSYREFADDVLPRIKANNYNTVOLMAIMEHSYYS
Query 211 SSEPRVNSYREFADDVLPRIKANNYNTVOLMAIMEHSYYS 251

►Query Query/295-504 matching Pfam-B 186

temp 295 ASNNVTDLNGFDIGQSQESYFHAGERYHKLWDSRLFNANWEVLRL 344
ASNNVTDLNGFDIGQSQESYFHAGERYHKLWDSRLFNANWEVLRL
Query 295 ASNNVTDLNGFDIGQSQESYFHAGERYHKLWDSRLFNANWEVLRL 344

temp 345 LSNLRWWLEEYNFDGFRDGTSMLYVHHGINMGFTGNYNFYFSEATDVD 394
LSNLRWWLEEYNFDGFRDGTSMLYVHHGINMGFTGNYNFYFSEATDVD
Query 345 LSNLRWWLEEYNFDGFRDGTSMLYVHHGINMGFTGNYNFYFSEATDVD 394

temp 395 AVVYLMANLIHKIFPDATVIAEDVSGMPGLSRPVSEGGIGFDYRLAMA 444
AVVYLMANLIHKIFPDATVIAEDVSGMPGLSRPVSEGGIGFDYRLAMA
Query 395 AVVYLMANLIHKIFPDATVIAEDVSGMPGLSRPVSEGGIGFDYRLAMA 444

temp 445 IPDKWIDYLNKNDEDSWKKEVTSSLNRRRYTEKCIAYAESHQSIQVGD 494
IPDKWIDYLNKNDEDSWKKEVTSSLNRRRYTEKCIAYAESHQSIQVGD
Query 445 IPDKWIDYLNKNDEDSWKKEVTSSLNRRRYTEKCIAYAESHQSIQVGD 494

temp 495 TIAFLLMNKE 504
TIAFLLMNKE
Query 495 TIAFLLMNKE 504

►Query Query/505-544 matching Pfam-B 1204

temp 505 MYSGMSCLTDASPVVDAGIALDKMIHFFHNGLGRRGVQPF 544
MYSGMSCLTDASPVVDAGIALDKMIHFFHNGLGRRGVQPF
Query 505 MYSGMSCLTDASPVVDAGIALDKMIHFFHNGLGRRGVQPF 544